SERVICEABILITY FEATURES OF SHEETS MADE FROM SELECTED COTTONS OF LOW AND HIGH FIBER ELONGATION

by

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CHAPTER I

INTRODUCTION

Throughout history cotton has proved a trustworthy servant of mankind. It has long been recognized as the most versatile and useful of all fibers. As long as cotton maintains this position of dominance, its fiber properties and their relations to the utilization of products made from cotton will be important areas of investigation.

Extensive research has been directed toward the properties of raw cotton, while there has been very little investigation of the relationship between cotton fiber properties and serviceability of the end product.

As a means of meeting this need and providing information which would be of benefit to cotton breeders, manufactureres and consumers, a research project was undertaken by Home Economics Research Personnel of six Southern states under the sponsorship of the United States Department of Agriculture and administered by the Experiment Stations of the Southern Region.

The major objective of this Regional Research Project, designated as SM-18,[1] was to indicate the relation of fiber length, strength, fineness and elongation to the end product performance. The first of these four properties under experimentation was fiber elongation. For this

[1]Technical Committee Project SM-18, "The Relation of Selected Properties of Raw Cotton to Product Quality and End Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

research, four bales of experimental cotton--two of low elongation and two of high elongation--were selected and manufactured into sheets which were subjected to use and laundering. Differences in serviceability were measured by laboratory tests performed at stated intervals of use and laundering (zero, fifth, fifteenth, thirtieth, forty-fifth, and sixtieth).

The purpose of this thesis was to determine the significance of differences in serviceability of the experimental cottons of high and low elongation. These differences were indicated by data from selected tests performed on sheets withdrawn for sampling at the zero, fifth, and fifteenth laundering intervals. To assure uniformity and speed in the computations of data the statistical designs were translated into programs for processing on a digital computer, Remington Rand Univac 1105.

Chapter II is a review of the literature pertaining to the effect of fiber properties upon fabric performance and to the use of the electronic digital computing system. Chapter III describes the procedure for the Regional Project, the procedure for this phase of the project, and the statistical design used. The compilation of data, the formulation of the Univac program, and the statistical significance of each variable are presented in Chapter IV. Chapter V includes the summary, conclusions, and recommendations for further study.

CHAPTER II

REVIEW OF LITERATURE

Relationship Between Cotton Fiber Properties and Serviceability of the End-Product

Our inquisitive ancestors, in their first century of Colonial life, seized every opportunity to experiment with all the growing things they found which appeared to be useful. The cotton plant was one of these useful products and from that day to the present, research in the field of cotton has been carried on. Previously this research had been directed mainly toward the segregated study of the properties of raw cotton.

The properties of cotton fibers and their relation to the utilization of products made from cotton have long been of primary concern to the cotton breeder and fabric manufacturer. Therefore, one of the main aims of current cotton fiber research is to indicate the influence of cotton fiber properties on the processibility and end-product quality of cotton.

> Fiber properties are those physical characteristics of a crop, a variety or a lot of cotton. They largely determine the properties of products made from it and influence its processing efficiency. It is generally accepted that the length, fineness, strength, maturity, length variability and grade of a cotton are the important physical traits which identify it as being either of good or poor quality.[2]

Since there is a complex inter-relationship between fiber properties, it has been difficult to ascribe an influence to a particular property.

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[2]Robert G. Cheatham and Louis A. Fiori, "Effect of Fiber Properties on Product Quality and Processing Efficiency," American Cotton Congress Proceedings, 1954, Vol. 15, p. 36.

However, due to new testing devices it is now possible to carry out investigations of the influence of a fiber property on the performance of the material made from that fiber.

The specific fiber property under consideration in this study was elongation. Fiber elongation is defined by Mauersberger as the deformation in the direction of load caused by tensile force. The deformation strain is measured at rupture and it is expressed as a percentage of the original length of the fiber. Elongations in cotton fibers range from four to ten per cent or more. The amount of elongation before actual rupture of a fiber is a safety factor that has considerable practical value. Rupture would occur instantaneously without warning if there were no elongation.[3]

Dr. Ludwig Rebenfeld, Director of the Textile Research Institute, has conducted several studies on cotton fibers. One of his more recent research projects was to determine in what manner cotton properties influence fabric performance. Using six cottons divided into three groups of two--a high breaking elongation group, an intermediate breaking elongation group, and a low breaking elongation group--Rebenfeld noted that the rate of fiber elongation decreased steadily due to processing through bleaching, mercerization, and resin-finishing. Cottons with a high breaking elongation exhibit a greater decrease in this property than cottons with a low breaking elongation. The fabric breaking elongation followed

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[3]Herbert R. Mauersberger, Matthew's Textile Fibers, (New York: John Wiley and Sons, Inc.), 1957, pp. 40-41.

the same pattern as the fiber breaking elongation, therefore indicating the influence of fiber properties on fabric performance.[4]

In a second study, Rebenfeld presented the relationship between the strength and extensibility of single cotton fibers and the corresponding properties of bundles, yarns, and fabrics, and he indicated the degree of transmission of single fiber properties to the properties of the resultant textile structure for several experimental cotton types. The study was evaluated by using single fibers, bundle fibers, single yarns, and two fabric constructions (sheeting and Oxford) which were available both in scoured and in a bleached, mercerized, and resin-finished condition. The results showed that bundle and yarn breaking elongations were well correlated with single fiber breaking elongation. Another interesting result was that in the case of fabric breaking elongation, the geometry of the textile structure plays a very important role. It was also noted that cottons with a low fiber breaking elongation transmit this property to the resultant textile structures more efficiently than do cottons with a high fiber breaking elongation.[5]

Sands, Fiori, and Brown, in trying to show how fiber properties--particularly strength--translate into fabric properties, drew the following conclusions:

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[4]L. Rebenfeld, "The Effect of Processing on Cotton Fiber Properties," Textile Research Journal, Vol. 27, No. 6, June, 1957, pp. 473-479.

[5]L. Rebenfeld, "Transmission of Cotton Fiber Strength and Extensibility," Textile Research Journal, Vol. 28, No. 7, (July, 1958), pp. 585-592.

1. The strongest fibered cotton produced the strongest fabric in the warp direction in gray, bleached and bleached and dyed states. In the filling direction this relationship did not hold for the bleached and bleached-dyed states.

2. Elongation at break of fabrics, after several chemical finishing processes, did not maintain the same ranking as fiber elongation.

3. Tearing resistance of the fabrics appeared to be correlated with cotton fiber strength.

4. There appeared to be no relationship between cotton fiber strength and fabric abrasion resistance except in the filling direction in the gray state.[6]

The majority of studies reviewed showed that more research has been directed toward fiber-yarn relationships than toward fiber-fabric relationships. The results of a study by Virgin and Wakeham suggested that yarn strength and yarn elongation are related to the single fiber properties, strength and elongation.[7] Soon after this, Hertel and Craven pointed out that the only yarn property found to be definitely correlated with fiber bundle elongation was yarn elongation.[8] Fiori, Brown, and Sands in evaluating three cottons varying in fiber elongation, found that the highest fiber elongation generally produced single and two-ply yarns

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[6]Jack E. Sands, Louis A. Fiori, and John J. Brown, "Comparison of Some Physical Properties of 80 x 80 Print Cloth Produced from Three Cottons Differing Primarily in Flat Bundle Strength," Textile Research Journal, Vol. 30, No. 5, (May, 1960), pp. 389-392.

[7]W. P. Virgin and Helmet Wakeham, "Cotton Quality and Fiber Properties--Part IV, The Relationship Between Single Fiber Properties and the Behavior of Bundles, Slivers, and Yarns," Textile Research Journal, Vol. 26, No. 3, (March, 1956), p. 177.

[8]K. L. Hertel and C. J. Craven, "Cotton Fiber Bundle Elongation and Tenacity as Related to Some Fiber and Yarn Properties," Textile Research Journal, Vol. 26, No. 6, (June, 1956), p. 484.

with the highest elongation. This relationship provides basis for stressing the probable importance of this fiber property as a contributor to yarn and fabric quality.[9]

This fact is further emphasized by Cheatham and Fiori.

> Yarn quality are those collective physical characteristics of a yarn which determine its service behavior as a component part of an end product and its consumer preference characteristics. Generally, the appearance, strength, uniformity and elongation of a yarn are the physical elements which determine its quality and its utilitarian value.[10]
>
> Limited studies conducted at the Southern Regional Research Laboratory have indicated that the fiber property, elongation, hitherto not considered important, may contribute to the elongation of both single and ply yarns. It was also found that fibers of high initial elongation produced yarns of unusually high elongation.[11]

Serviceability of Sheets

Two of the more recent research projects on serviceability of sheets are the one by McLendon and Davison of the United States Department of Agriculture and the study by Partida of Washington State University.

The sheets used in the United States Department of Agriculture study were of three types of fabric--all cotton, all rayon, and a fifty-fifty blend of cotton and rayon--identical in construction. Laboratory tests were made on yarns, finished fabrics, and on the laundered-only and laundered-and-used sheetings.

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[9]Louis A. Fiori, John J. Brown, and Jack E. Sands, "The Effect of Cotton Fiber Strength on the Properties of Two-Ply Carded Yarns," Textile Research Journal, Vol. 26, No. 4, (April, 1956), p. 299.

[10]Cheatham and Fiori, op. cit., p. 36.

[11]Ibid., p. 37.

The dry breaking strengths of the all-cotton and the all-rayon yarns were higher than the blends and that of the all-cotton was greater than the all-rayon. The all-rayon yarns elongated the most and the all-cotton the least. In general, the results of measurements of dry-breaking strength and elongation on the gray fabrics paralleled those found for the yarns.[12]

The results of some physical measurements on the finished sheeting showed, as in the yarns, the all-cotton sheeting having the highest breaking strength, followed by the all-rayons and the blends. The all-rayon fabrics had the greatest elongation (both wet and dry), but the all-cotton showed a greater elongation than most of the blended sheetings. The all-cotton fabric weighed the least and the all-rayon the most, and the thread count followed the same ranking.[13]

During the first five laundering periods, the all-rayon sheets shrank 18 per cent, the blend 12 per cent, and the all-cotton 8 per cent in the warp direction. All sheets stretched approximately 5 per cent in the filling direction. As a result of these dimensional changes, these sheets increased in weight and also in count and breaking strength fillingwise. The weight of the sheets decreased slightly as the result of repeated laundering and wear. The breaking strength of the sheets decreased

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[12]Verda I. McLendon and Suzanne Davison, Serviceability of Sheets Composed Wholly or in Part of Cotton and Viscose Staple Rayon, United States Department of Agriculture, Technical Bulletin No. 1103 (Washington: Government Printing Office, 1955), p. 7.

[13]Ibid., pp. 8-9.

progressively as the number of launderings increased, and the loss in strength for all three fabrics was about the same. The cotton and cotton-rayon sheets showed that damage was greatest in the area occupied by the shoulders, while the rayon sheets showed no difference in damage between areas within the sheets. The per cent elongation of the fabrics decreased as the number of launderings increased, and in all cases, the all-rayon sheets showed the greatest elongation and the all-cotton the least. Microscopic examination of fibers taken from the sheets showed a progressive increase in damage as the number of launderings increased. After the first five launderings, the damage in the rayon fibers was greater than in the cotton fibers.[14]

The second study compared two types of muslin sheets--heavy weight and medium weight and two methods of laundering--commercial laundry procedure and special laundry procedure. The sheets were used in both boys' and girls' dormitories. Reflectance value, yarn count, breaking strength and elongation were the tests made on the sheets to check their performance. These tests were made after five, twenty, forty, and sixty launderings.[15]

From the test results, it was indicated that the type of muslin had much less influence on the retention of whiteness than the sex of the users and the laundry method. Yarn counts showed that use and laundering

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[14] Ibid., pp. 56-57.

[15] Elvira L. Partida, Serviceability of Dormitory Sheets, Washington Agricultural Experiment Station, Institute of Agriculture Sciences, Washington State University, Bulletin 617, 1960, pp. 1-3.

altered sheet dimensions by shrinking in length and stretching in width. Most of this shrinkage occurred in the first twenty launderings. The maximum loss of strength occurred during the first twenty launderings and the center areas of the sheets suffered the greatest strength loss. Sheets laundered by the special laundry method lost more strength and it was found that the girls' sheets were stronger at the end of the project. There was a slight increase in elongation up to the twentieth laundering and then elongation diminished during the following periods. The heavy muslin sheets had lower elongation when new, but a gain in elongation in the first period, and a constant loss by the medium weight sheets gave the heavy sheets the largest percentage of elongation at the end. The special laundry method showed greater loss in elongation than the regular commerical laundering. Paralleling the strength pattern, loss of elongation was greatest at the center of the sheet and by the end of the experiment, the girls' sheets had a higher elongation percentage.[16]

Use of the Electronic Computer for Data Processing

It is interesting to note that the basic idea of the electronic computer was borrowed from a Frenchman, named Jacques, who in 1745 succeeded in controlling a loom by means of cards with punched holes. Borrowing from Jacques' idea and building upon the work of others, Charles Babbage, an Englishman, attempted to design the first computer.[17] Many

[16] Ibid., pp. 29-30.

[17] Ned Chapin, An Introduction to Automatic Computers, (New Jersey: D. Van Nostrand Company, Inc.), 1957, p. 225.

developments have come about since Professor Babbage of Cambridge University designed (but did not complete) the original computer in the 1830's. Later history recorded a Russian-made computer built by Soviet scientists in 1911 for solving differential equations. However, the United States received credit for completing the first truly electronic machine which was built in 1945.[18]

Ten years later there were only a few dozen computer installations, mostly used by physicists and mathematicians to solve scientific problems. Today there are 11,000 electronic computers in operation. Although these machines vary in physical appearance (from desk-size models to complex systems that fill six-story buildings) and cost (from $20,000 to $7 million), their operational principle is basically the same. Each has memory storage systems and each is given a "program" which instructs its electronic circuits in solving a problem. In current use this growing population of computers is affecting more and more people.[19]

The electronic machines are agents of the "second industrial revolution." As Westinghouse physicist Robert Ramey expressed it, "in the first revolution, the steam engine augmented human muscle power. Now we are augmenting human brain power."

For an automatic computer to solve a problem, human beings must first develop a way of solving the problem and then instruct the computer

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[18] The Computer at Chapel Hill. North Carolina: The Computation Center, 1960, p. 8.

[19] Warren R. Young, "The Machines Are Taking Over," Life, Vol. 50, No. 9, (March 3, 1961), p. 109.

in how to solve the problem when given the data. The human operation of instructing the automatic computer is called "programming," and the resulting set of instructions is called a "program." Without a program, an electronic computer cannot do any data processing.[20]

Automatic programming allows the computer itself to do much of the problem preparation. The term "automatic" is used because the machine itself handles most of the clerical details after the human operator states the solution technique for his problem. By doing this, the machine saves a large amount of human effort and time.[21]

One particular automatic programming system is the Internal Translator language. The IT language was originated at Carnegie Institute of Technology by A. J. Perlis, Joseph Smith, and Harold Van Zoeren for the IBM Type 650. Later versions of this same language that can be used with the Univac 1103-A and 1105 were developed in cooperation with this group by the Ramo-Wooldridge Corporation and the Lockheed Missiles Division.[22]

Computers are becoming increasingly popular as a research tool in fields as varied as chemistry, city planning, forestry, mathematics, business administration, languages, and textiles.[23] This rise in

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[20]Chapin, Op. Cit., p. 12.

[21]Automatic Programming Using the "IT" Compilers for the Univac 1105 and IBM 650. Research Computation Center, The Consolidated University of North Carolina, April, 1959, p. I-1.

[22]Ibid., p. I-2.

[23]The Computer at Chapel Hill. Op. Cit., p. 1.

popularity in textile research is illustrated by Franklin E. Newton:

> Fast and economical statistical analysis of a large amount of data, accumulated over the past several years, has been made possible through use of electronic data processing equipment. Use of electronic equipment has thus increased our pace considerably in evaluating fiber and spinning properties.[24]

When programmed properly, the main virtues of the computers are their incredible speeds and unfailing reliability. As Professor John G. Truxal of the Polytechnic Institute of Brookly points out, "they never get fatigued, never get bored, their attention never wanders, and they never make subjective errors."[25]

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[24]Franklin E. Newton, "A New Look at Cotton Quality Relationships," Textile Industries, Vol. 124, No. 9, (September, 1960), p. 133.

[25]Edwin Diamond and Henry Simmons, "Machines Are This Smart," Newsweek, Vol. 56, No. 10, (October 24, 1960), pp. 85-86.

CHAPTER III

METHOD OF PROCEDURE

Since this study is a contributing part of the Southern Regional Research Project, the data and some of the procedures included in this thesis are taken from the project.[26]

Regional Research Project SM-18

For the Regional Project, four types of experimental strains of cotton were selected. All four were carefully chosen for their similarity in length, strength, and fineness. The chief difference was in fiber elongation. This difference between the cotton types is referred to as "high" and "low" elongation cottons--with cottons one and two having "low" elongation and cottons three and four having "high" elongation.

A contract was arranged with the School of Textiles at Clemson College for processing the four bales of cotton into type 140 muslin sheeting and for making this material into single bed sheets according to commercial specifications. A different colored yarn was woven into the sheets of each of the four types of cotton to serve as a means of identification. One-fourth (approximately 200) of the total number of sheets of each cotton type was shipped to the four states responsible for the use testing--Alabama, Missouri, North Carolina, and Oklahoma.

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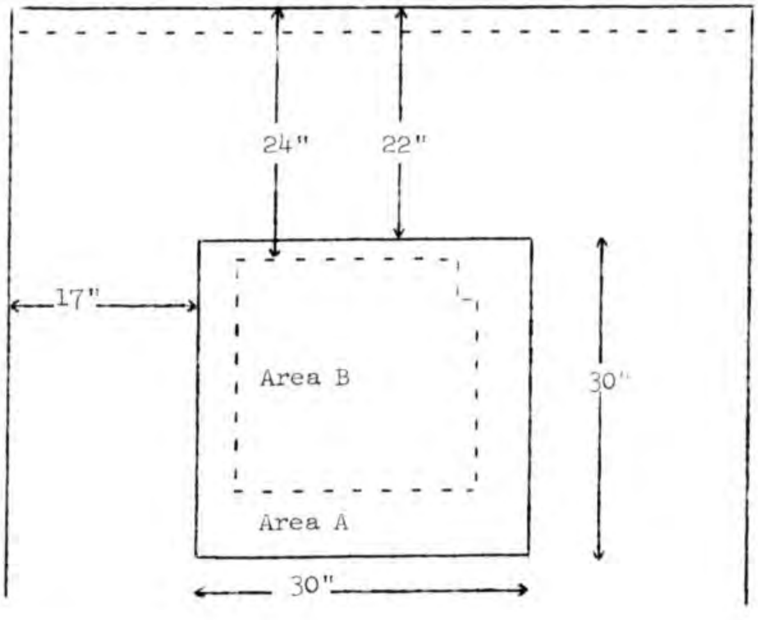
[26] Technical Committee Project SM-18, "The Relation of Selected Properties of Raw Cottons to Product Quality and End Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

The sheets were desized by sending them through a normal laundering procedure and then they were coded. Six sheets of each type to be used as originals or as samples at the zero interval were taken out and marked for all tests to be made at that interval.

Since February 1959 the sheets have been in service in women's dormitories at Auburn University, The University of Missouri, The Woman's College of the University of North Carolina, and at Oklahoma State University. At the end of each week of use, the sheets were collected and sent to commercial laundries. Samples consisting of six sheets of each of the four types of cotton were withdrawn for laboratory testing at the fifth and fifteenth intervals of use and laundering. By using a standard template, the testing area of each sample sheet was marked as illustrated.[27]



Area A
Thread Count
Dimensional Change

Area B
Fabric Weight
Tearing Strength
Breaking Strength
Fabric Elongation

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[27] Ibid., p. 5.

Thread count, fabric weight, dimensional change, tearing strength, breaking strength, and fabric elongation were the laboratory tests performed after each laundering interval to measure the differences in serviceability of the cottons. Test procedures were based on those given in the ASTM Standards on Textile Materials for November, 1957.

Analysis of Variance

Data from these physical tests performed on six sheet samples of each cotton type at the zero, fifth, and fifteenth intervals were received from the stations making the laboratory tests. The statistical evaluation of these data was the analysis of variance for each test: thread count, fabric weight, dimensional change, tearing strength, breaking strength, and fabric elongation.

The analysis of variance for both a single variable of classification and multiple variables of classification are employed in the Regional Project. Although this thesis covers only the last and summarizing series of analyses, there are four series used in the Regional Project. On the following pages are diagrams illustrating and explaining each series of analyses. Each of the four classifications of analysis of variance is labeled with the corresponding number of the computer program for that classification. In each step there was a replicate of six sheets for each of the cotton types, therefore, each block or cell in the diagrams represents six sheets.

Step I. A series of analyses of a single variable of classification. Each physical test is applied to the six replicate sheets in each cotton type at each of the four locations following each of the stated washing intervals.

For example, the shaded portion of the diagram represents only the analysis of variance of one physical test (such as warp tearing strength) applied to sheets which were classified into four categories according to cotton type, from Oklahoma at the zero interval.

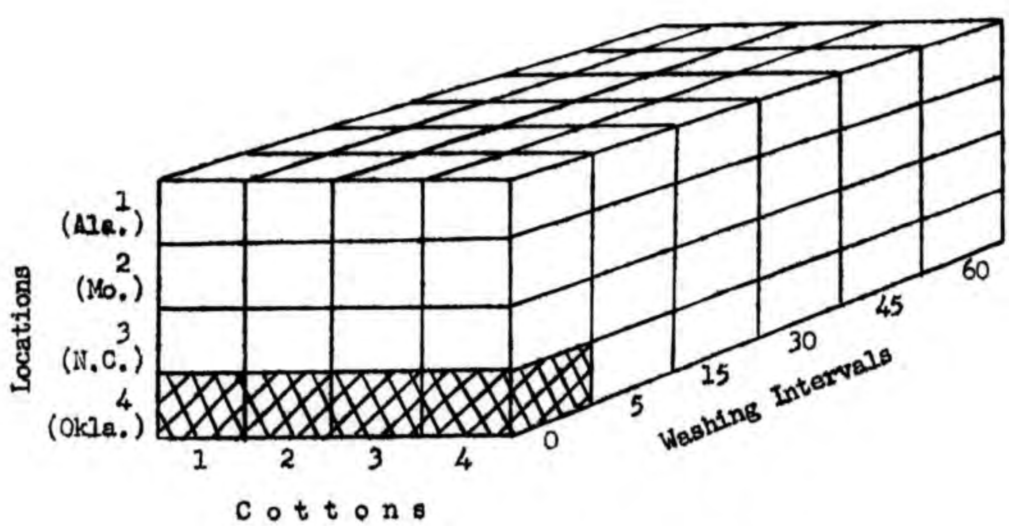

Figure 1. Step I. Diagram of Single Variable of Classification

Step II. A series of analyses of two variables of classification composed of each test applied to the four types of cotton at each location over all washing intervals as they are completed.

For example, the shaded portion represents only the analysis of variance of one physical test (such as warp tearing strength) applied to sheets of the four types of cotton, from Oklahoma at the zero and fifth intervals.

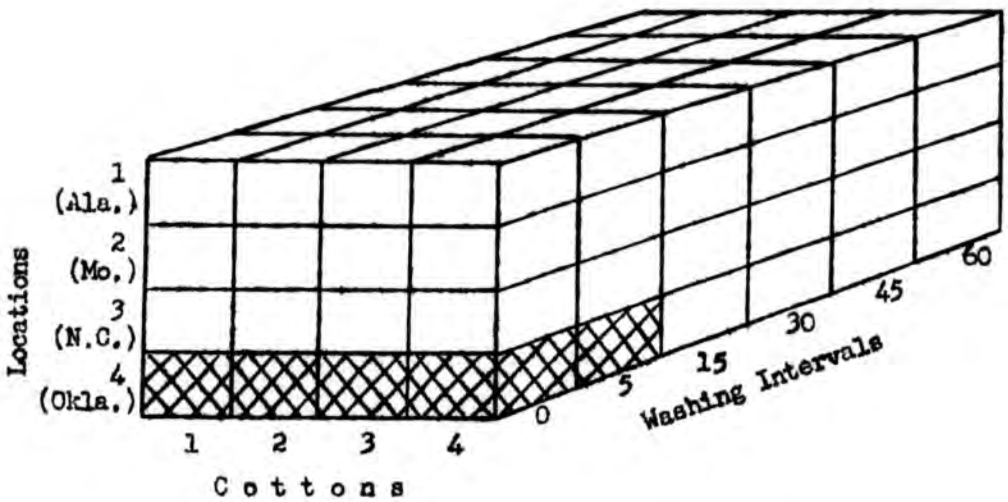

Figure 2. Step II. Diagram of Two Variables of Classification

Step III. A series of analyses of two variables of classification made up of each test applied to the four types of cotton over all locations at each washing interval.

For example, the shaded portion represents only the analysis of variance of one physical test (such as warp tearing strength) applied to sheets of the four types of cotton from Oklahoma, North Carolina, Missouri, and Alabama at the zero interval.

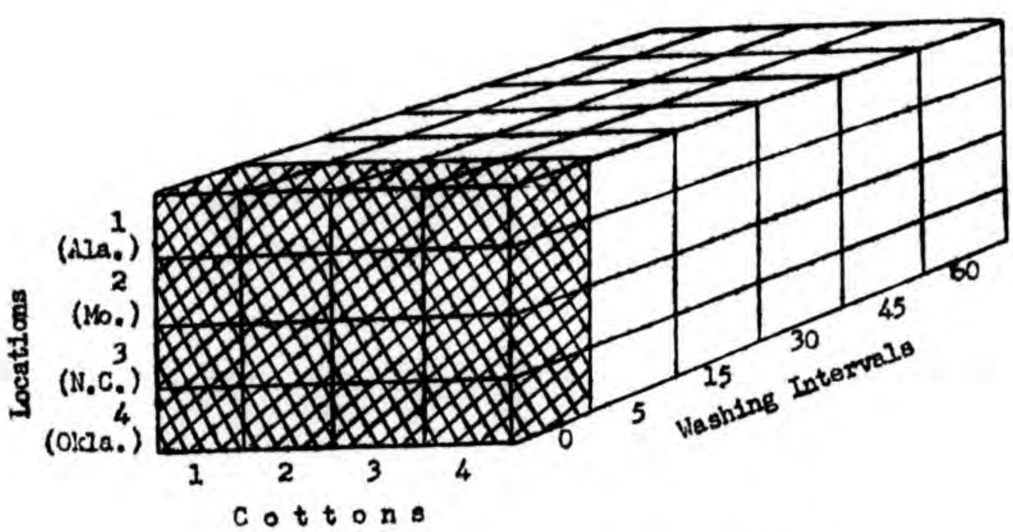

Figure 3. Step III. Diagram of Two Variables of Classification

Step IV. A series of analyses of three variables of classification using each test applied to the four types of cotton over all locations over all washing intervals as they are completed.

For example, the shaded portion represents only the analysis of variance of one physical test (such as warp tearing strength) applied to sheets of the four types of cotton, from Oklahoma, North Carolina, Missouri, and Alabama at the zero and fifth intervals.

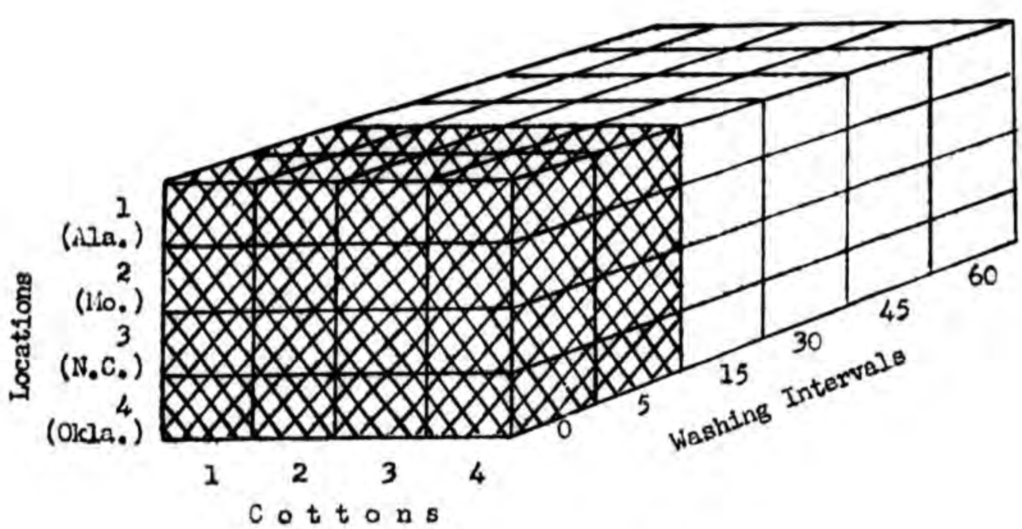

Figure 4. Step IV. Diagram of Three Variables of Classification

The fourth step was the one used in this study to summarize the differences in the performance features of the four cottons--two of high elongation and two of low elongation.

With assistance from the regional project statistician, a design for the analysis of variance was prepared. This design combines the data from all the stations for summarizing the two interval (zero-five) interaction.

TABLE I

ANALYSIS OF VARIANCE PATTERN

(Zero-Fifth Intervals)

Source of Variation	Degrees of Freedom	
Cottons		c-1 = 3
Low vs. High	$\frac{c}{2} - 1 = 1$	
Between Lows	$\frac{c}{2} - 1 = 1$	
Between High	$\frac{c}{2} - 1 = 1$	
Washings		w-1 = 1
Locations		l-1 = 3
C x W		(c-1) (w-1) = 3
C x L		(c-1) (l-1) = 9
W x L		(w-1) (l-1) = 3
C x W x L		(c-1) (w-1) (l-1) = 9
Sheets treated alike		cwl (s-1) = 160
Total		T - 1 = 191

c = Cottons
w = Washing intervals
l = Locations
s = Replicates of sheets in each block

The same design was followed for summarizing the three-interval (zero-five-fifteen) interaction.

TABLE II

ANALYSIS OF VARIANCE PATTERN

(Zero-Fifth-Fifteenth Intervals)

Source of Variation	Degrees of Freedom
Cottons	c-1 = 3
Low vs. High	$\frac{c}{2} - 1 = 1$
Between Lows	$\frac{c}{2} - 1 = 1$
Between High	$\frac{c}{2} - 1 = 1$
Washings	w-1 = 2
Locations	l-1 = 3
C x W	(c-1) (w-1) = 6
C x L	(c-1) (l-1) = 9
W x L	(w-1) (l-1) = 6
C x W x L	(c-1) (w-1) (l-1) = 18
Sheets treated alike	cwl (s-1) = 240
Total	T - 1 = 287

c = Cottons l = Locations
w = Washing intervals s = Replicates of sheets in each block

Remington Rand 1105 Digital Computer

The statistical design was then taken as a problem to be solved by means of a high speed computer. The Univac Scientific 1105 Digital

Computer in the Research Computation Center of the Consolidated University of North Carolina was available for this purpose.

The planning of a detailed program for the analysis of variance was one of the aims of this thesis. A more comprehensive explanation of the plan of this program will be given in Chapter IV. A program was prepared for the computer by translating the statistical procedures into the IT (Internal Translator) language. This program is a set of coded instructions in proper sequence which directs the computer in its various operations of receiving a problem, solving it, and transmitting the result, together with the data involved in the problem itself.

In general, "Y" values were assigned to fixed data and each step in the statistical procedure was given a "Z" value. The program made up of these "Y" and "Z" values along with the data involved was changed into a form to be inserted in the computer. The computer then followed the program, solving the problem by performing the specified actions upon the data. The results of the completed computations were recorded on paper.

From this paper, the computations for the analysis of variance were decoded. The "F" values, indicating significance of differences were transcribed into summarizing statements for the zero-five and the zero-five-fifteen laundering and use intervals of the pairs of sheets.

CHAPTER IV

PRESENTATION OF DATA

The major objective of this thesis was to determine whether differences existed between the serviceability of sheets made of cottons differing in fiber elongation. To test the validity of these differences, the statistical technique, analysis of variance, was used. A minor objective of the thesis was to translate the statistical design into a program for processing on the electronic computer.

Compilation of Data

Six sheets from each cotton type were withdrawn at the zero, fifth, and fifteenth laundering intervals. Samples for laboratory testing were cut and mailed to the stations making the tests. Physical tests measuring thread count, fabric weight, dimensional change, tearing strength, breaking strength, and fabric elongation were made for each of the twenty-four sheets (six of each cotton type) from each of the four states. The number of samples for each physical test varied. For example, two measurements proved to be sufficient for warp thread count while it was necessary to make seven tests for warp tearing strength.

All of the data from the test results were sent to North Carolina for processing. The outline of the statistical evaluation of these data was given in Chapter III. The data for this thesis were taken from the computations made in Step I of the processing. In each physical test the six means (one from the several measurements on each sheet sample) were totaled according to each cotton type. These summations of means, the sum of all the means for each state and the sum of squares for the sheets treated alike were taken from results in Step I and compiled in Appendix A--Table 1 for the zero interval, Table 2 for the fifth interval and Table 3 for the fifteenth interval. The means of physical measurements of each cotton type also were taken from Step I of the data computation. These means are given in Appendix B--Tables 1, 2, and 3 for intervals zero, five, and fifteen, respectively.

Analysis of Variance

So that several factors associated with possible sources of variability could be studied simultaneously, the analysis of variance for three variables of classification was used. The three variables were the cottons, the locations, and the washing intervals. The analysis of variance technique also enabled investigation of the interaction effects of these three factors. Separate analyses were made for each physical test after the zero-five intervals and after the zero-five-fifteen intervals. Therefore, the units being tested for significance in this study consisted of the means of the numerical scores of the test results computed after the zero, fifth, and fifteenth intervals. These means are found in Appendix A, Tables 1, 2, and 3.

The analysis of variance for three variables of classification yielded the following mean squares:[28]

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[28] W. J. Dixon, F. J. Massey, Introduction to Statistical Analysis (New York: McGraw-Hill Book Company, Inc., 1951), pp. 119-139.

1. <u>three</u> for the main effects plus <u>three</u> for the breakdown of one main effect into individual degrees of freedom

    a. mean square between cottons

        (1) mean square between cottons of high and low elongation

        (2) mean square within cottons of low elongation

        (3) mean square within cottons of high elongation

    b. mean square between washing intervals

    c. mean square between locations

2. <u>three</u> for the first-order interactions (between two variables)

    a. mean square for interaction between the cottons and washing intervals

    b. mean square for interaction between the cottons and locations

    c. mean square for interaction between the washing intervals and locations

3. <u>one</u> for the second-order interaction (among three variables)

    a. mean square for interaction of cottons, washing intervals, and locations

4. <u>one</u> for the within groups of means

    a. mean square of sheets treated alike

If the second-order interaction was significant, it was used as the error term to test the mean square of the interaction between the cottons and washing intervals. The remaining first-order interactions were tested using the within mean square as the error term. If the interaction between the washing intervals and locations was significant, it was used as the error term to test for significance the mean square of the washing interval sources of variation. If the interaction between the cottons and locations was significant, it was used to test the mean square of the cottons and the breakdown of cottons for significance. Whenever a first or second-order interaction was used as the error term, in preference to the within group mean square, the degrees of freedom were replaced by those which corresponded with the associated ratios.[29]

The null hypothesis, asserting that no significant difference existed, was employed, and the 1 per cent and 5 per cent levels of significance were selected for determining the acceptance or rejection of the hypothesis.

Computer Program

In preparation of the computer program the data from each of the six laboratory tests were tabulated. The table form was planned so that data from each physical test would have a "Y" value. An example of this (Table III) with data from the warp thread count test at the zero and fifth intervals is given on the following page. Both the computer program and the data tables were planned so that they can be used throughout the total number of washing intervals needed for the Southern Regional Project. This was made possible by allowing spaces on both data tables and computer program for additional test results and for data computations of future intervals without altering the program pattern or the table form.

The statistical procedure for the analysis of variance for three variables of classification and the necessary computations for carrying

[29]Information obtained from Regional Project Statistician.

TABLE III

EXAMPLE OF DATA TABLE WHICH ACCOMPANIED COMPUTER PROGRAM

Test Thread Count (Warp)

Intervals 0-5

Step IV A

State	Cottons	Washing Intervals											
		0		5		15		30		45		60	
		Y		Y		Y		Y		Y		Y	
Alabama	1	1	454.00	25	449.00	49		73		97		121	
	2	2	454.00	26	446.00	50		74		98		122	
	3	3	456.00	27	444.00	51		75		99		123	
	4	4	459.00	28	451.00	52		76		100		124	
	Total	5	1823.00	29	1790.00	53		77		101		125	
	S.T.A.*	6	12.1670	30	15.0004	54		78		102		126	
Missouri	1	7	451.00	31	443.00	55		79		103		127	
	2	8	452.00	32	451.00	56		80		104		128	
	3	9	449.00	33	439.00	57		81		105		129	
	4	10	456.00	34	443.00	58		82		106		130	
	Total	11	1808.00	35	1776.00	59		83		107		131	
	S.T.A.	12	3.0005	36	25.3333	60		84		108		132	
North Carolina	1	13	455.00	37	444.00	61		85		109		133	
	2	14	454.00	38	444.00	62		86		110		134	
	3	15	451.00	39	442.00	63		87		111		135	
	4	16	455.00	40	441.00	64		88		112		136	
	Total	17	1815.00	41	1771.00	65		89		113		137	
	S.T.A.	18	5.8340	42	20.8332	66		90		114		138	
Oklahoma	1	19	458.00	43	462.00	67		91		115		139	
	2	20	458.00	44	460.00	68		92		116		140	
	3	21	462.00	45	462.00	69		93		117		141	
	4	22	461.00	46	461.00	70		94		118		142	
	Total	23	1839.00	47	1845.00	71		95		119		143	
	S.T.A.	24	3.5005	48	8.1667	72		96		120		144	

*Sheets treated alike.

out the procedure made up the pattern for the program. In this particular program "Y" values were assigned to the summation of means of six sheets within each cotton type, to the grand total of the test means of all four cottons, and to the sum of squares of the sheets treated alike of each state. This is illustrated for warp thread count at the zero-five intervals in Table III. The raw data with their assigned "Y" values for all physical measurements are found in Appendix A, Tables 1, 2, and 3. "Z" values were given to the computation results. In the program, instructions for typing out needed information were included after the directions for carrying out the statistical procedure. The program was then put on punched cards which interpreted to the computer the allocation of the storage of data and the statements necessary for the solution of the problem. Tables (such as Table III) containing the data from the laboratory tests and their assigned "Y" values were included with each program. The data from these tables were recorded on paper tape. The punched cards and paper tape were inserted into the computer which followed the program instructions. The results from the completed computations were put on magnetic tape and then recorded on paper. From this paper the sum of squares, the mean squares, and the F values were taken to complete the analysis of variance table for each physical test. An example of the guide for decoding the computation results that completed the analysis of variance tables is given as Table IV. There was an analysis of variance table for each test for the zero-five intervals and for the zero-five-fifteen intervals. These tables are included in the appendix as Appendix C, Tables 1 through 11 for the zero-five intervals and Appendix D, Tables 1 through 11 for the zero-five-fifteen intervals.

The program translating the statistical design into the IT (Internal Translator) language is reproduced below:

STEP IV A

Summarizing Interaction of <u>Two</u> Intervals

```
 N 0020   Y 0048   Z 00116   S 0010   W 0000               TH
1. 2, NO, 1, 1, 20,                                         F
2. NNO = 0                                                  F
3. Interaction - Two Intervals                    INPUT     F
4. AT   (33285996544)                                       F
5. AT N1        AT N20                                      F
6. T (0.)                                                   F
7. T (0.)                                                   F
   Z 1  = Y1 + Y7 + Y13 + Y19                               F
   Z 2  = Y2 + Y8 + Y14 + Y20                               F
   Z 3  = Y3 + Y9 + Y15 + Y21                               F
   Z 4  = Y4 + Y10 + Y16 + Y22                              F
   Z 5  = Y5 + Y11 + Y17 + Y23                              F

   Z 6  = Y25 + Y31 + Y37 + Y43                             F
   Z 7  = Y26 + Y32 + Y38 + Y44                             F
   Z 8  = Y27 + Y33 + Y39 + Y45                             F
   Z 9  = Y28 + Y34 + Y40 + Y46                             F
   Z 10 = Y29 + Y35 + Y41 + Y47                             F

   Z 31 = Y1 + Y25                                          F
   Z 32 = Y2 + Y26                                          F
   Z 33 = Y3 + Y27                                          F
   Z 34 = Y4 + Y28                                          F
   Z 35 = Y5 + Y29                                          F

   Z 36 = Y7 + Y31                                          F
   Z 37 = Y8 + Y32                                          F
   Z 38 = Y9 + Y33                                          F
   Z 39 = Y10 + Y34                                         F
   Z 40 = Y11 + Y35                                         F
```

Z 41 = Y13 + Y37 F
Z 42 = Y14 + Y38 F
Z 43 = Y15 + Y39 F
Z 44 = Y16 + Y40 F
Z 45 = Y17 + Y41 F

Z 46 = Y19 + Y43 F
Z 47 = Y20 + Y44 F
Z 48 = Y21 + Y45 F
Z 49 = Y22 + Y46 F
Z 50 = Y23 + Y47 F

Z 51 = Z31 + Z36 + Z41 + Z46 F
Z 52 = Z32 + Z37 + Z42 + Z47 F
Z 53 = Z33 + Z38 + Z43 + Z48 F
Z 54 = Z34 + Z39 + Z44 + Z49 F
Z 55 = Z35 + Z40 + Z45 + Z50 F

Z 56 = (Y1 x Y1) + (Y2 x Y2) + (Y3 x Y3) + (Y4 x Y4) F
Z 57 = (Y7 x Y7) + (Y8 x Y8) + (Y9 x Y9) + (Y10 x Y10) F
Z 58 = (Y13 x Y13) + (Y14 x Y14) + (Y15 x Y15) + (Y16 x Y16) F
Z 59 = (Y19 x Y19) + (Y20 x Y20) + (Y21 x Y21) + (Y22 x Y22) F
Z 60 = (Y25 x Y25) + (Y26 x Y26) + (Y27 x Y27) + (Y28 x Y28) F
Z 61 = (Y31 x Y31) + (Y32 x Y32) + (Y33 x Y33) + (Y34 x Y34) F
Z 62 = (Y37 x Y37) + (Y38 x Y38) + (Y39 x Y39) + (Y40 x Y40) F
Z 63 = (Y43 x Y43) + (Y44 x Y44) + (Y45 x Y45) + (Y46 x Y46) F

Z 80 = (Z31 x Z31) + (Z32 x Z32) + (Z33 x Z33) + (Z34 x Z34) F
Z 81 = (Z36 x Z36) + (Z37 x Z37) + (Z38 x Z38) + (Z39 x Z39) F
Z 82 = (Z41 x Z41) + (Z42 x Z42) + (Z43 x Z43) + (Z44 x Z44) F
Z 83 = (Z46 x Z46) + (Z47 x Z47) + (Z48 x Z48) + (Z49 x Z49) F
Z 84 = Y6 + Y12 + Y18 + Y24 + Y30 + Y36 + Y42 + Y48 F

Z 85 = (Z55 x Z55)/ 192. F

Z 86 = (((Z51 x Z51) + (Z52 x Z52) + (Z53 x Z53) +
(Z54 x Z54))/ 48.) - Z85 F

Z 87 = ((((Z51 + Z52) x (Z51 + Z52)) + ((Z53 + Z54) x (Z53 +
Z54)))/ 96.) - Z85 F

Z 88 = (((Z51 x Z51) + (Z52 x Z52))/ 48.) - (((Z51 + Z52) x
(Z51 + Z52))/ 96.) F

Z 89 = (((Z53 x Z53) + (Z54 x Z54))/ 48.) - (((Z53 + Z54) x
(Z53 + Z54))/ 96.) F

Z 90 = (((Z5 x Z5) + (Z10 x Z10))/ 96.) - Z85 F

Z 91 = (((Z35 x Z35) + (Z40 x Z40) + (Z45 x Z45) +
(Z50 x Z50))/ 48.) - Z85 F

Z 92 = (((Z1 x Z1) + (Z2 x Z2) + (Z3 x Z3) + (Z4 x Z4) +
(Z6 x Z6) + (Z7 x Z7) + (Z8 x Z8) + (Z9 x Z9))/ 24.) -
(Z85 + Z86 + Z90) F

Z 0 = (Z31 x Z31) + (Z32 x Z32) + (Z33 x Z33) + (Z34 x Z34) +
(Z36 x Z36) + (Z37 x Z37) + (Z38 x Z38) + (Z39 x Z39) +
(Z41 x Z41) + (Z42 x Z42) F

Z 93 = ((Z0 + (Z43 x Z43) + (Z44 x Z44) + (Z46 x Z46) +
(Z47 x Z47) + (Z48 x Z48) + (Z49 x Z49))/ 12.) -
(Z85 + Z86 + Z91) F

Z 94 = (((Y5 x Y5) + (Y11 x Y11) + (Y17 x Y17) + (Y23 x Y23) +
(Y29 x Y29) + (Y35 x Y35) + (Y41 x Y41) +
(Y47 x Y47))/ 24.) - (Z85 + Z90 + Z91) F

Z 95 = ((Z56 + Z57 + Z58 + Z59 + Z60 + Z61 + Z62 + Z63)/ 6.) -
(Z85 + Z86 + Z90 + Z91 + Z92 + Z93 + Z94) F

Z 96 = Z86/ 3. F

Z 97 = Z87/ 1. F

Z 98 = Z88/ 1. F

Z 99 = Z89/ 1. F

Z 100 = Z90/ 1. F

Z 101 = Z91/ 3. F

Z 102 = Z92/ 3. F

Z 103 = Z93/ 9. F

Z 104 = Z94/ 3. F

Z 105 = Z95/ 9. F

Z 106 = Z84/ 160. F

Z 107 = Z96/ Z106 F

Z 108 = Z97/ Z106 F

Z 109 = Z98/ Z106 F

```
    Z 110 = Z99/ Z106                                F
    Z 111 = Z100/ Z106                               F
    Z 112 = Z101/ Z106                               F
    Z 113 = Z102/ Z106                               F
    Z 114 = Z103/ Z106                               F
    Z 115 = Z104/ Z106                               F
    Z 116 = Z105/ Z106                               F
    8, NO, 1, 1, 10,                                 F
 8. T NO   T ZNO   T (0.)   T (0.)                   F
    9, NO, 31, 1, 63,                                F
 9. T NO   T ZNO   T (0.)   T (0.)                   F
    10, NO, 80, 1, 116,                              F
10. T NO   T ZNO   T (0.)   T (0.)                   F
    G 1                                              FF
```

Explanation of Program Symbols

Step IV A is the number of the computer program for the analysis of variance for three variables of classification using each test over all states over the zero-five washing intervals. Step IV B is the number of the computer program for the zero-five-fifteen washing intervals.

The phrase, "Summarizing Interaction of Two Intervals" refers to the zero-five washing intervals.

In the next line of the program:

N 0020 = number of variables used in the program heading
Y 0048 = number of "Y" values used in the program
Z 00116 = number of "Z" values used in the program
S 0010 = number of type out statements in the program
W 0000 = number of subroutines in the program

Statement 1 (2, NO, 1, 1, 20,) is an iteration statement instructing the machine to vary NO from 1 to 20 in steps of 1 through statement 2.

Statement 2 (NNO = 0) sets the program variables N1 through N20 equal to 0. N1 through N20 contain the information for one line of heading, and it must be cleared before the heading is read in by statement 3.

Statement 3 reads in the "Y" variables and it may contain any meaningful information as long as the word "INPUT" is the last thing on the line.

Statement 4 causes a new page to begin so that each column of data for each physical measurement is on a separate page.

Statement 5 types out the heading which was read in by statement 3.

Statements 6 and 7 each provide one space between the heading and the answers ("Z" variables) which are typed out by the program.

"Z1" through "Z83" and "Z85" are mathematical computations needed in the analysis of variance.

"Z84" through "116" are the mathematical computations of the analysis of variance, and they are decoded as shown in Table IV.

Statement 8 instructs the machine to type out the results of "Z1" through "Z10". Statement 9 asks for the results of "Z31" through "Z63" and statement 10 instructs the computer to type out the answers of "Z80" through "Z116".

TABLE IV

EXAMPLE OF GUIDE FOR DECODING COMPUTER RESULTS

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	*F* Values
Cottons	3	Z 86	Z 96	Z 107
Low vs. High	1	Z 87	Z 97	Z 108
Between Lows	1	Z 88	Z 98	Z 109
Between Highs	1	Z 89	Z 99	Z 110
Washing Intervals		Z 90	Z 100	Z 111
Locations		Z 91	Z 101	Z 112
C x W		Z 92	Z 102	Z 113
C x L		Z 93	Z 103	Z 114
W x L		Z 94	Z 104	Z 115
C x W x L		Z 95	Z 105	Z 116
Sheets treated alike		Z 84	Z 106	

On the final line of the program, "G 1" instructs the computer to go back to statement 1 and read in data for another physical test until all data have been processed.

"F" indicates the end of a single computation and "FF" the end of the total program.

Discussion of Findings

Using the data in Tables 1, 2, and 3 of Appendix B, the means of the physical measurements of the low elongation and the means of the high elongation cottons for each of the four states at each interval (zero, five, and fifteen) were computed. These results are presented in Table V. This table further summarizes these differences by indicating a mean of the four states for both low and high elongation cottons at each of the above intervals.

The means of the low elongation cottons and the means of the high elongation cottons for the combined states at each interval were compared in graph form in Figures 5, 6, 7, 8, 9, and 10. The comparison of low and high elongation cottons indicated small differences in fabric weight, thread count, and dimensional change (Figures 5, 6, and 7). More noticeable differences between the cottons of low and high elongation were apparent in the graphs depicting tearing strength, breaking strength, and fabric elongation measurements (Figures 8, 9, and 10).

For the analysis of variance tables, the F values of the cottons, washing intervals, locations and interactions for the zero-five intervals, and the zero-five-fifteen intervals for each physical test were decoded from the computer report sheets. These F values are summarized in Table VI.

TABLE V

MEANS OF PHYSICAL MEASUREMENTS OF LOW AND HIGH ELONGATION COTTONS

	State	Thread Count (Yarns per inch)		Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent)		Tearing Strength 100 G/CM		Breaking Strength (Pounds)		Elongation (Per Cent)	
		Warp	Filling		Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
ZERO INTERVAL												
Low Elongation*	Alabama	75.7	70.3	4.82	No tests made at this interval		12.10	11.31	61.8	73.4	17.7	19.4
	Missouri	75.3	70.5	4.95			12.70	11.93	59.1	69.8	15.4	17.9
	North Carolina	75.8	70.6	4.87			13.56	12.17	57.2	65.4	14.9	17.8
	Oklahoma	76.3	70.1	5.02			11.69	11.04	59.4	70.1	15.2	18.9
	Mean	75.8	70.4	4.92			12.51	11.61	59.4	69.7	15.8	18.5
High Elongation**	Alabama	76.2	70.5	4.84			11.08	10.18	58.8	69.4	19.8	22.2
	Missouri	75.4	70.8	4.98			10.55	9.72	58.0	65.5	17.7	20.0
	North Carolina	75.5	70.3	4.88			10.81	9.57	57.0	63.2	17.0	20.1
	Oklahoma	76.9	70.0	5.02			11.61	10.45	57.3	66.2	16.9	21.2
	Mean	76.0	70.4	4.93			11.01	9.98	57.8	66.1	17.8	20.9
FIFTH INTERVAL												
Low Elongation	Alabama	74.6	70.3	4.84	-0.1	+0.4	15.12	13.15	57.0	67.9	14.7	16.5
	Missouri	74.5	72.1	4.99	-1.1	+0.6	14.43	12.97	53.7	66.9	16.7	17.8
	North Carolina	74.0	71.5	4.87	-1.6	+2.0	13.36	12.33	50.6	64.2	16.3	16.1
	Oklahoma	76.8	70.8	5.02	-0.6	+0.4	15.99	13.73	52.2	58.5	14.3	16.1
	Mean	75.0	71.2	4.93	-0.8	+0.8	14.72	13.04	53.4	64.4	15.5	16.6
High Elongation	Alabama	74.6	70.0	4.86	-0.2	+0.4	14.46	12.20	53.4	64.5	16.9	18.2
	Missouri	73.5	71.7	4.97	-0.4	+0.4	13.48	11.47	52.2	61.0	18.5	19.4
	North Carolina	73.6	71.8	4.85	-1.7	+1.5	12.14	10.66	49.7	61.2	18.0	18.1
	Oklahoma	76.9	71.0	5.09	-0.7	+0.3	14.11	12.08	51.9	57.9	16.0	17.7
	Mean	74.6	71.1	4.94	-0.8	+0.6	13.55	11.60	51.8	61.2	17.4	18.4
FIFTEENTH INTERVAL												
Low Elongation	Alabama	76.2	71.5	4.86	-0.8	-0.1	12.88	11.48	52.7	63.0	15.5	17.4
	Missouri	74.2	70.6	4.94	-1.2	+1.4	11.87	10.97	48.4	59.6	15.7	15.8
	North Carolina	75.2	71.8	4.84	-1.8	+0.5	11.48	10.14	43.5	51.9	14.2	15.1
	Oklahoma	76.1	71.8	5.00	-1.9	+0.8	12.47	10.71	47.6	55.0	17.7	19.0
	Mean	75.4	71.4	4.91	-1.4	+0.6	12.18	10.82	48.0	57.4	15.8	16.8
High Elongation	Alabama	75.8	72.3	4.90	-1.2	-0.8	12.34	10.55	51.9	60.4	17.3	19.2
	Missouri	73.8	70.8	4.92	-0.7	+1.3	11.43	10.00	46.5	57.3	17.3	17.5
	North Carolina	75.4	72.0	4.80	-1.8	+0.4	10.44	8.88	42.1	49.0	15.8	16.9
	Oklahoma	76.3	71.8	5.05	-1.9	+0.4	11.53	9.92	45.7	53.4	17.9	19.0
	Mean Mean	75.3	71.7	4.92	-1.4	+0.3	11.44	9.84	46.6	55.0	17.0	18.2

* Low = cottons 1 and 2

**High = cottons 3 and 4

TABLE VI

F VALUES OF COTTONS, WASHING INTERVALS, LOCATIONS, AND INTERACTIONS

Source	Degrees of Freedom	Thread Count Warp	Thread Count Filling	Fabric Weight	Dimensional Change Warp	Dimensional Change Filling	Tearing Strength Warp	Tearing Strength Filling	Breaking Strength Warp	Breaking Strength Filling	Elongation Warp	Elongation Filling
0-5 INTERVAL												
Cottons	3	1.08	20.74**	5.84*	1.54	5.96**	6.84*	14.96**	1.92	8.43**	52.26**	36.42**
Low vs. High	1	<1	<1	1.80	<1	2.86	20.01**	44.56**	5.06	21.27**	141.74**	101.91**
Between Low	1	<1	43.30**	3.28	0.00	2.39	<1	<1	<1	3.91	1.50	<1
Between High	1	3.17	18.92**	12.44**	3.90	12.63**	<1	<1	<1	<1	13.55**	7.34*
Washing Intervals	1	5.55	4.83	5.88*	6.46	4.60	13.48*	20.20*	250.84**	8.20	<1	9.82
Locations	3	77.60**	12.02**	163.28**	21.12**	30.19**	12.04**	9.96**	19.93**	36.82**	56.44**	15.55**
C x W	3	2.64	1.30	<1	1.54	5.96**	1.38	1.02	<1	1.34	2.28	3.38*
C x L	9	2.71**	<1	2.10*	1.16	1.87	6.80**	6.74**	3.50	2.98**	2.67**	2.98**
W x L	3	16.97**	7.04**	1.54	21.12**	30.19**	31.79**	14.78**	1.05	17.44**	92.82**	35.77**
C x W x S	9	1.14	1.48	3.17**	1.16	1.87	4.70**	3.31**	<1	3.38**	2.15*	1.36*
Sheets Treated Alike	160											
Total	191											
0-5-15 INTERVAL												
Cottons	3	4.87**	25.79**	4.12*	<1	4.02*	9.91**	21.23**	3.27	28.03**	18.13**	18.89**
Low vs. High	1	1.62	<1	1.05	<1	4.42	28.12**	62.46**	9.04*	78.92**	49.31**	53.49**
Between Low	1	<1	53.64**	2.80	<1	<1	1.60	<1	<1	5.15*	<1	<1
Between High	1	13.03**	23.28**	8.51*	<1	7.40*	<1	<1	<1	<1	4.96	2.83
Washing Intervals	2	2.98	3.60	<1	12.90*	1.60	15.60**	23.81**	71.78**	23.97**	<1	6.16*
Locations	3	98.72**	3.96**	193.36**	26.46**	33.15**	31.92**	28.54**	72.36**	92.73**	32.68**	57.46**
C x W	6	1.18	<1	<1	1.18	1.83	1.46	1.84	<1	1.42	2.00	1.69
C x L	9	1.90	<1	3.53**	1.74	1.93	6.45**	6.08**	3.33	1.68	8.86**	7.22**
W x L	6	15.02**	10.66**	5.46**	11.80**	35.42**	22.13**	12.66**	7.28	16.30**	97.60**	42.17**
C x W x S	18	1.36	1.24	1.85*	<1	1.68*	4.16**	2.62**	<1	3.03**	5.33**	4.11**
Sheets Treated Alike	240											
Total	287											

*Significant at .05 level.

**Significant at .01 level.

<u>Fabric weight</u>. There was a very slight difference between the mean fabric weight of the high and low elongation cottons at all three washing intervals (Figure 5). The weight of all the sheets changed only minutely from the zero to the fifteenth laundering. There was a small weight increase at the fifth interval and a slight decrease at the fifteenth interval.

Analysis of variance of fabric weight of the sheets indicates that the following were significant for the:

A. Zero-five intervals
   1. the high elongation cottons
   2. the locations
   3. the interaction of cottons, washing intervals, and locations

B. Zero-five-fifteen intervals
   1. the locations
   2. the interaction of cottons and locations
   3. the interaction of washing intervals and locations

<u>Thread count</u>. There was a slight decrease in the mean warp thread count of both low and high elongation cottons after the fifth laundering. The fifteenth interval showed a slight increase over the fifth interval. The mean filling thread count of both low and high elongation cottons showed a slight increase after both the fifth and fifteenth washing intervals (Figure 6). Comparison of thread counts showed greater variation after the fifteenth washing in the thread counts of the high elongation cottons than in the counts of the low elongation cottons. The differences in filling thread count in the four cottons were not differences between the cottons of low and high elongation as groups. Instead, cottons 1 and 4 had consistantly lower filling thread counts than cottons 2 and 3 at all three washing intervals.

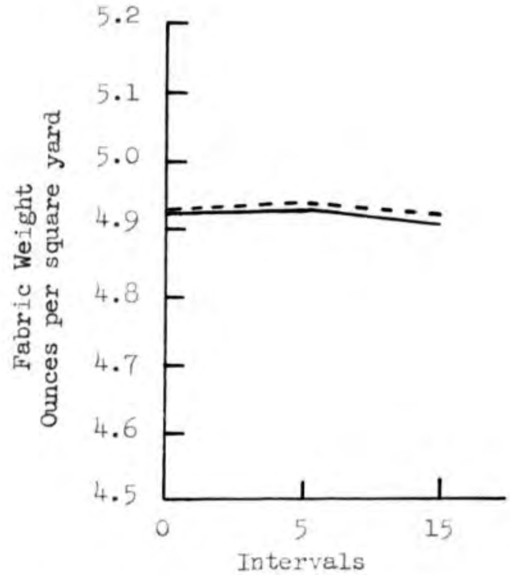

Figure 5. Means of Fabric Weight of Low and High Elongation Cottons

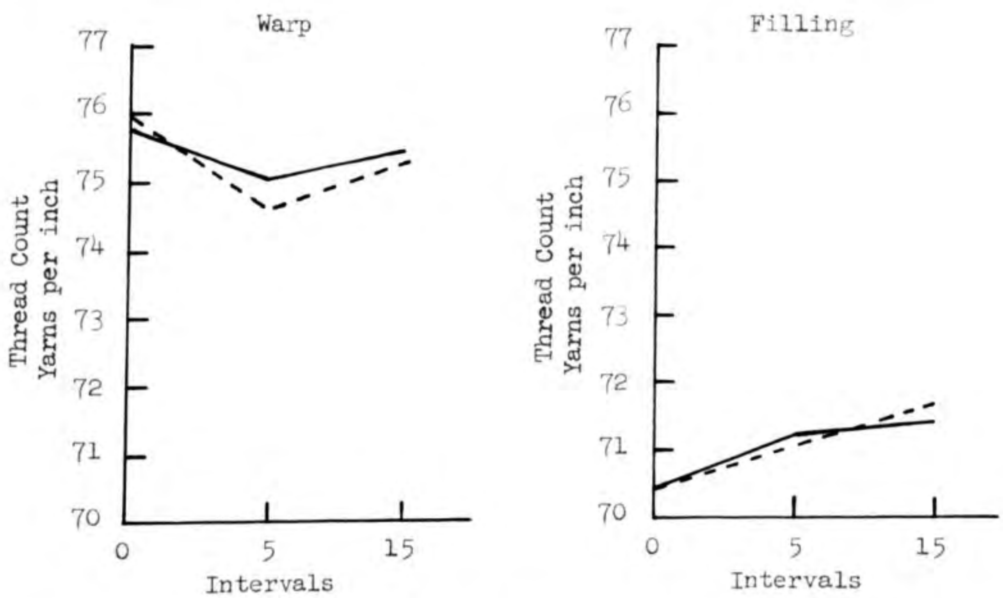

Figure 6. Means of Thread Count of Low and High Elongation Cottons

Key:

_____ Mean of low elongation cottons

\- - - Mean of high elongation cottons

Analysis of variance of warp thread count of the sheets indicates that the following were significant for the:

A. Zero-five intervals
   1. the locations where the sheets were used
   2. the interaction of types of cotton and locations
   3. the interaction of washing intervals and locations

B. Zero-five-fifteen intervals
   1. the four types of cotton
   2. the high elongation cottons
   3. the locations
   4. the interaction of cotton types, washing intervals and locations

Analysis of variance of filling thread count of the sheets indicates that the following were significant for both the zero-five intervals and the zero-five-fifteen intervals:

1. The four types of cotton
2. The low elongation cottons
3. The high elongation cottons
4. The locations
5. The interaction of washing intervals and locations

Dimensional change. All of the means of the four cottons used in the four states showed shrinkage in the warp direction after both the fifth and fifteenth launderings. The differences between the means of the low and high elongation cottons were very small (Figure 7). After the fifth and fifteenth launderings, all of the means showed stretch in the filling direction with the exception of the high and low elongation cottons from Alabama at the fifteenth interval. The greatest filling dimensional change took place during the first five launderings. The sheets of low elongation cottons stretched slightly more than the high elongation cottons in the filling direction. However, there was greater variation in means of filling dimensional change of high elongation

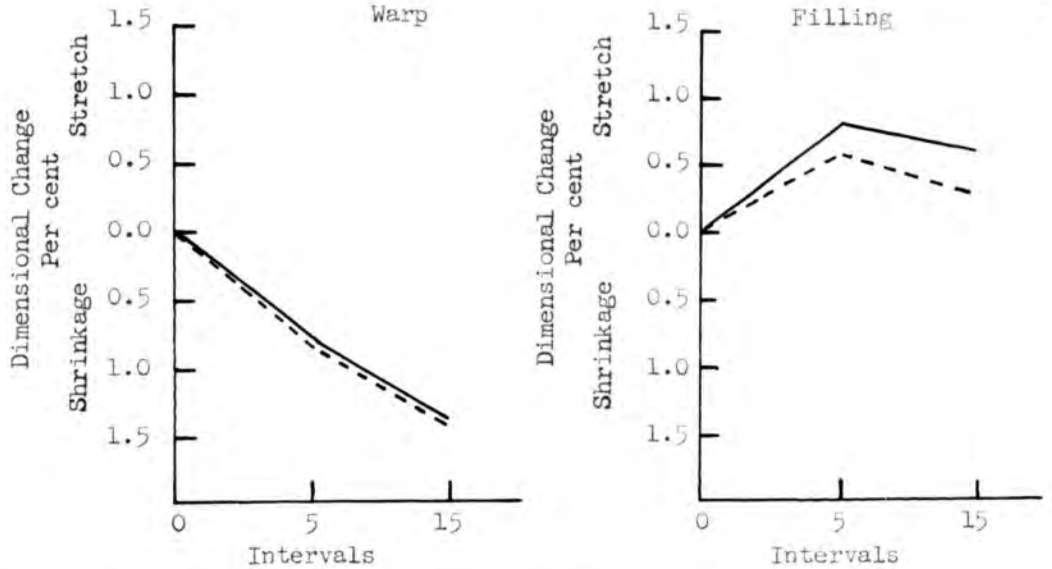

Figure 7. Means of Dimensional Change of Low and High Elongation Cottons

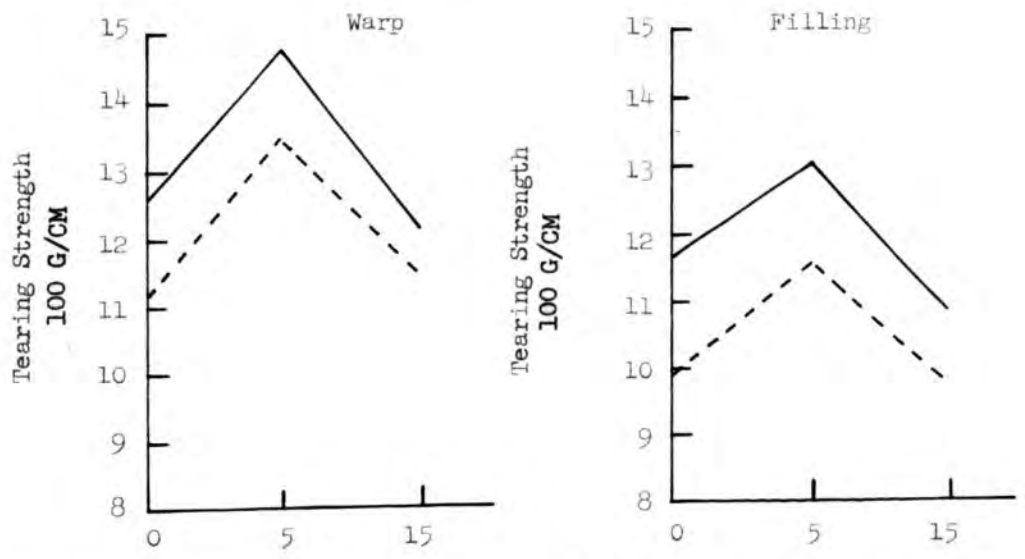

Figure 8. Means of Tearing Strength of Low and High Elongation Cottons

Key:

——— Mean of low elongation cottons
\- - - Mean of high elongation cottons

cottons after the fifth washing than in the means of the filling dimensional change of the low elongation cottons. This difference was also present after the fifteenth interval, but the percentage of difference was much less than the percentage of difference at the fifth interval.

Analysis of variance of warp dimensional change of the sheets indicates that the following were significant for both the zero-five intervals and zero-five-fifteen intervals:

1. The locations
2. The interaction of the washing intervals and locations

Analysis of variance of filling dimensional change of the sheets indicates that the following were significant for the:

A. Zero-five intervals
   1. the four types of cotton
   2. the high elongation cottons
   3. the locations
   4. the interaction of the cottons and the washing intervals
   5. the interaction of the washing intervals and locations

B. Zero-five-fifteen intervals
   1. the locations
   2. the interaction of the washing intervals and locations

Tearing strength. The tearing strength means of the low elongation cottons were greater than the high elongation cottons in both warp and filling directions at all three intervals. This is shown in Figure 8. In comparing the means at the three intervals, the low elongation cottons were 12 per cent stronger originally than the high elongation cottons, 8 per cent stronger at the fifth interval and 6 per cent stronger at the fifteenth interval. The pattern of the warp tearing strength is also followed by the filling tearing strength.

The low elongation cottons were 14 per cent stronger than the high elongation cottons at the beginning of the study, 11 per cent stronger at the fifth interval and 9 per cent stronger at the fifteenth interval. There was a rise in tearing strength means of all sheets from the zero to the fifth interval, and then there was a decrease in tearing strength means at the fifteenth interval.

Analysis of variance of warp tearing strength of the sheets indicates that the following were significant for the:

A. Zero-five intervals
   1. the low versus high elongation cottons
   2. the locations
   3. the interaction of cottons and locations
   4. the interaction of washing intervals and locations
   5. the interaction of cottons, washing intervals and locations

B. Zero-five-fifteen intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the washing intervals
   4. the locations
   5. the interaction of cottons and locations
   6. the interaction of washing intervals and locations
   7. the interaction of cotton, washing intervals, and locations

Analysis of variance for filling tearing strength indicates that the following were significant for the:

A. Zero-five intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the locations
   4. the interaction of cottons and locations
   5. the interaction of washing intervals and locations
   6. the interaction of cottons, washing intervals, and locations

B. Zero-five-fifteen intervals
1. the four types of cotton
2. the low versus high elongation cottons
3. the washing intervals
4. the locations
5. the interaction of cottons and locations
6. the interaction of washing intervals and locations
7. the interaction of cottons, washing intervals, and locations

Breaking strength. The gradual loss of strength is important in judging the serviceability of cotton sheets. The loss of breaking strength of the sheets differing in fiber elongation was compared in Figure 9. The means for both warp and filling tests showed that the breaking strength of the low elongation cottons was also greater than the breaking strength of the high elongation cottons. The differences, however, were not as great as those in tearing strength. Comparing the low and high elongation cottons in terms of percentage differences, the warp of the low elongation cottons was slightly stronger throughout--2.7 per cent at the zero interval, 3 per cent at the fifth interval, and 3 per cent at the fifteenth interval; while the filling of low elongation cottons was 5 per cent stronger at the zero and fifth intervals and 4.2 per cent stronger at the fifteenth interval.

Analysis of variance of warp breaking strength of the sheets indicates that the following were significant for both the zero-five intervals and the zero-five-fifteen intervals:

1. The washing intervals
2. The locations

Analysis of variance of filling breaking strength of the sheets indicates that the following were significant for the:

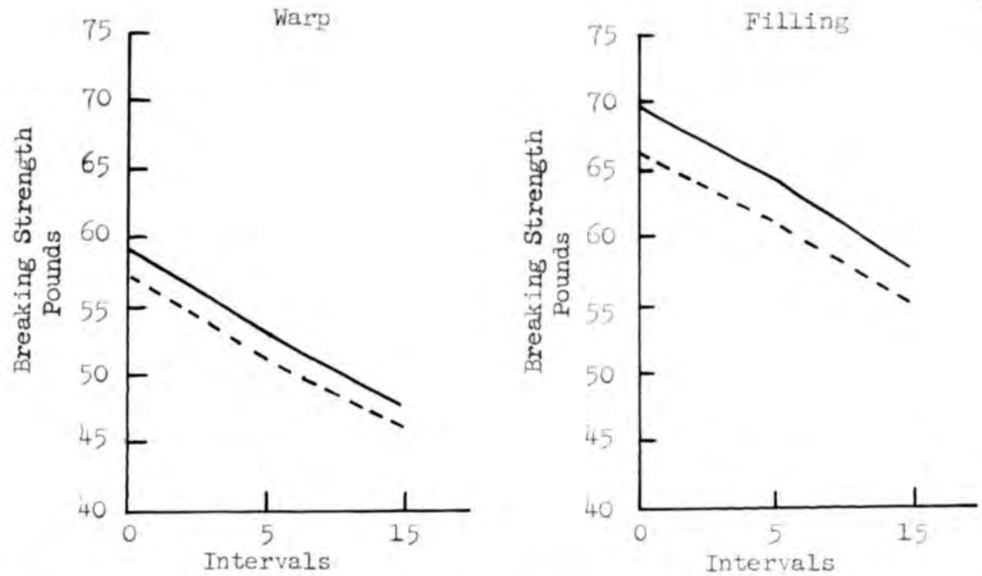

Figure 9. Means of Breaking Strength of Low and High Elongation Cottons

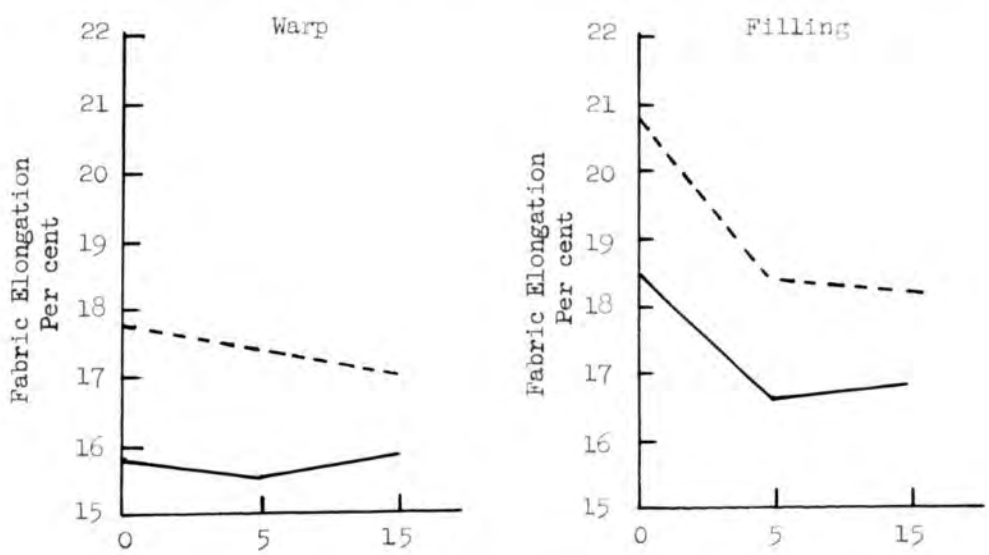

Figure 10. Means of Fabric Elongation of Low and High Elongation Cottons

Key:

——— Mean of low elongation cottons
\- - - Mean of high elongation cottons

A. Zero-five intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the locations
   4. the interaction of the cottons and locations
   5. the interaction of the washing intervals and locations
   6. the interaction of the cottons, washing intervals and locations

B. Zero-five-fifteen intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the washing intervals
   4. the locations
   5. the interaction of the washing intervals and locations
   6. the interaction of the cottons, washing intervals and locations

Fabric elongation. Fabric elongation is represented graphically in Figure 10. In comparing the percentage of fabric elongation of the cottons of high and low fiber elongation, the low elongation cottons were consistently lower than the high elongation cottons at the zero, fifth, and fifteenth intervals in both warp and filling directions. This agreed with the findings of Rebenfeld that fabric breaking elongation follows the same pattern as the fiber breaking elongation.[30] The elongation means for the warp direction of the low elongation cottons were 15.8, 15.5, and 15.8 for intervals zero, five, and fifteen respectively and the warp direction of the high elongation cottons, 17.8, 17.4, and 17.0. The high elongation cottons had 2.0 percentage points greater elongation at the zero interval, 1.9 percentage points greater elongation

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[30] L. Rebenfeld, "The Effect of Processing on Cotton Fiber Properties," Textile Research Journal, Vol. 27, No. 6, June, 1957, pp. 473-479.

at the fifth interval, and 1.2 percentage points greater elongation at the fifteenth interval. For the filling direction, the elongation means of the low elongation cottons were 18.5, 16.6, and 16.8, and the means of the high elongation cottons were 20.9, 18.4, and 18.2. As in the warp direction, the high elongation cottons elongated more than the low elongation cottons. This difference was 2.4 percentage points higher at the zero interval, 1.8 percentage points higher at the fifth interval, and 1.6 percentage points higher at the fifteenth interval.

Analysis of variance of warp elongation of the sheets indicates that the following were significant for the:

A. Zero-five intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the high elongation cottons
   4. the locations
   5. the interaction of the cottons and locations
   6. the interaction of the washing intervals and locations

B. Zero-five-fifteen intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the locations
   4. the interaction of the cottons and locations
   5. the interaction of the washing intervals and locations
   6. the interaction of the cottons, washing intervals, and locations

Analysis of variance of filling fabric elongation of the sheets indicates that the following were significant for the:

A. Zero-five intervals
   1. the four types of cotton
   2. the low versus high elongation cottons
   3. the locations
   4. the interaction of the cottons and locations
   5. the interaction of the washing intervals and locations

B. Zero-five-fifteen intervals
1. the four types of cotton
2. the low versus high elongation cottons
3. the locations
4. the interaction of cottons and locations
5. the interaction of washing intervals and locations
6. the interaction of cottons, washing intervals, and locations

Summary of all the physical tests. The primary purpose of this thesis was to study the differences in serviceability of fabrics made from fibers differing in elongation. There were several differences which were statistically significant between the sheets of low elongation cotton and those made of high elongation cotton. The significant differences between the cottons of low elongation and the cottons of high elongation were in the following measurements:

1. warp tearing strength
2. filling tearing strength
3. filling breaking strength
4. warp fabric elongation
5. filling fabric elongation

The low elongation cottons had the greater strength, while the high elongation cottons had the highest fabric elongation.

The differences among sheets used and laundered at different locations were significant in the analysis of every physical measurement. Since this was true, the interactions involving the locations were also statistically significant. These variations in locations, which were anticipated in the original planning of the Regional Project, were probably due to differences in laundering procedure and testing conditions in the various states.

It was apparent that similarity of fiber elongation did not result in similar response to all of the physical tests. There were statistically significant differences among the four cottons in the following measurements:

1. warp thread count
2. filling thread count
3. filling dimensional change
4. warp tearing strength
5. filling tearing strength
6. filling breaking strength
7. warp fabric elongation
8. filling fabric elongation

In general, the low elongation cottons were more alike in response to the physical measurements than the high elongation cottons. There were significant differences between the two cottons both of which had high elongation in the following measurements:

1. warp thread count
2. filling thread count
3. fabric weight
4. filling dimensional change
5. warp fabric elongation

There were significant differences between the two cottons both of which had low elongation in the following measurement:

1. filling thread count

Since the gradual loss of strength was considered in judging performance of the cotton sheets, it was important to note that the washing intervals caused changes in strength. There were statistically significant differences between the washing intervals in the strength measurements--both warp and filling tearing strength and warp and filling breaking strength.

CHAPTER V

SUMMARY AND CONCLUSIONS

Cotton has been one of the most valuable household textiles for many years. Knowledge of its fiber properties and their relationship to the performance-in-use of products made from cotton will be important to cotton breeders, manufacturers, and consumers.

There has been little investigation of the effect of fiber properties on serviceability. In answer to this need, a research project was undertaken by Home Economics Research Personnel of six Southern states under the direction of the Agricultural Research Service of the United States Department of Agriculture. This project designated as Regional Research Project SM-18, was concerned with the relation of fiber length, strength, fineness and elongation to the end product performance. The first of these four properties under experimentation was fiber elongation.

To determine the performance of the four types of cotton--two of low elongation and two of high elongation--sheets were manufactured and used in the women's dormitories of four of the colleges taking part in this project. The sheets were laundered in commercial laundries, and six sheets of each cotton type were withdrawn as samples for laboratory testing at the zero, fifth, and fifteenth laundering intervals at each use station. Laboratory tests, measuring sheet performance, used in this study were thread count, fabric weight, dimensional change, tearing strength, breaking strength and fabric elongation.

The purposes of this study, a contributing part of the Southern Regional Research Project, were:

1. To determine the significance of differences in serviceability of sheets made from cottons of low and high fiber elongation, used and laundered at four states.

2. To prepare a design for the analysis of variance combining all states over zero-five and zero-five-fifteen laundering intervals.

3. To translate the statistical design into the language of the IT compiler and prepare a program for processing the data on the Remington Rand 1105 at Chapel Hill, North Carolina.

The results of the laboratory tests provided the data. The statistical evaluation of these data was a series of analyses of three variables of classification using the means of each test applied to the four types of cotton over all locations over the zero-five washing intervals and the zero-five-fifteen washing intervals. The three variables were the cottons, the locations, and the washing intervals. The variability among cottons was broken down into individual degrees of freedom to make comparisons between the sheets of low and high fiber elongation.

Translating the statistical design into the IT language and processing the data on an electronic computer proved highly successful. Since this was found to be an efficient method of computing the data for this thesis, it will be even more valuable for the completed project due to the extensiveness of the data for the entire project. Thus, the data from the future intervals of the project can be analyzed quickly, easily, and economically by means of the electronic computer.

From the computer report sheets, the F values, which would indicate significance of differences, were taken. In summarizing the data from the zero-five intervals, it was found that there were statistically significant differences:

1. Between the cottons of low and high elongation in both warp and filling tearing strength
2. Between the cottons of low and high elongation in filling breaking strength
3. Between the cottons of low and high elongation in both filling and warp fabric elongation
4. Between the low elongation cottons in filling thread count
5. Between the high elongation cottons in filling thread count
6. Between the high elongation cottons in fabric weight
7. Between the washing intervals in the warp breaking strength
8. Among the locations in all physical tests

In summarizing the data from the zero-five-fifteen intervals, it was found that there were statistically significant differences:

1. Between the cottons of low and high elongation in both warp and filling tearing strength
2. Between the cottons of low and high elongation in filling breaking strength
3. Between the cottons of low and high elongation in both warp and filling fabric elongation
4. Between the low elongation cottons in filling thread count
5. Between the high elongation cottons in warp and filling thread count
6. Among the washing intervals in warp and filling tearing strength and warp and filling breaking strength
7. Among the locations in all physical tests

From these findings, the following conclusions were made:

1. There were statistically significant differences in serviceability (as measured by physical tests) of sheets made from cottons of low and high fiber elongation. The low elongation cottons had the greater strength, while the high elongation cottons had the highest fabric elongation.

2. The low elongation sheets were more similar in response to the physical measurements than the high elongation sheets.

3. There were significant differences among the four locations at which the sheets were used and laundered.

4. There were statistically significant differences between the washing intervals in the strength measurements.

It is suggested that a study of data from other physical tests used to measure sheet performance be made for verification of the conclusions made in this thesis. Since this study included only one-fourth of the entire Regional Project, it also would be of interest to follow the same serviceability measurements through the sixtieth washing intervals. This would determine differences in serviceability features which would undoubtedly be influenced by the two types of cotton under investigation.

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APPENDIX

APPENDIX A

SUMMATION OF MEANS* OF PHYSICAL MEASUREMENTS ACCORDING TO COTTONS TESTED IN THE FOUR STATES

TABLE 1. COMPILATION OF DATA FROM MEASUREMENTS MADE AT THE ZERO INTERVAL

State	Cottons	Y Values Assigned	Thread Count (Yarns per inch)		Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent)		Tearing Strength 100 G/CM		Breaking Strength (Pounds)		Elongation (Per Cent)	
			Warp	Filling		Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
Alabama	1	1	454.00	420.00	29.17			73.07	68.49	376.70	462.30	104.70	118.70
	2	2	454.00	424.00	28.69			72.08	67.21	365.80	418.60	107.40	114.60
	3	3	456.00	425.00	29.11			68.03	62.10	358.40	424.70	120.30	139.60
	4	4	459.00	421.00	29.01	No measure-		64.89	59.97	346.70	407.60	117.00	127.30
	Total	5	1823.00	1690.00	115.98			278.07	257.77	1447.60	1713.20	449.40	500.20
	S.T.A.**	6	12.1670	8.9998	0.0651	ments made		5.2393	6.2302	136.4434	152.3481	18.6500	40.4100
Missouri	1	7	451.00	421.00	29.74	at this		77.61	72.70	349.50	430.60	92.90	106.60
	2	8	452.00	425.00	29.62			74.83	70.45	360.10	407.30	92.40	108.10
	3	9	449.00	425.00	29.45	interval		64.44	58.08	339.60	385.00	106.90	120.10
	4	10	456.00	424.00	30.25			62.18	58.54	356.10	401.40	105.70	119.70
	Total	11	1808.00	1695.00	119.06			279.06	259.77	1405.30	1624.30	397.90	454.50
	S.T.A.	12	3.0005	5.8330	0.0450			13.5270	7.6191	107.7180	111.6538	6.8449	5.7649
North Carolina	1	13	455.00	421.00	29.31			75.83	69.12	356.60	394.70	88.90	106.60
	2	14	454.00	426.00	29.12			86.87	76.91	330.10	390.40	89.70	107.00
	3	15	451.00	424.00	29.05			58.11	52.01	345.60	389.10	105.20	121.50
	4	16	455.00	420.00	29.47			71.62	62.80	338.20	369.30	98.80	119.60
	Total	17	1815.00	1691.00	116.95			292.43	260.84	1370.50	1543.50	382.60	454.70
	S.T.A.	18	5.8340	8.1665	0.0546			14.8309	11.0887	107.7148	170.9512	5.0099	7.2149
Oklahoma	1	19	458.00	416.00	30.22			71.25	67.32	358.70	433.10	94.00	115.30
	2	20	458.00	425.00	30.00			69.00	65.10	353.60	408.20	88.00	111.70
	3	21	462.00	423.00	30.02			67.55	61.36	345.30	403.60	102.60	130.70
	4	22	461.00	417.00	30.18			71.79	64.02	342.80	391.10	100.60	124.20
	Total	23	1839.00	1681.00	120.42			279.59	257.80	1400.40	1636.00	385.20	481.90
	S.T.A.	24	3.5005	7.1665	0.0399			2.5874	2.9033	81.2890	134.2620	19.4999	13.3451

*Means of six sheets.

**Sum of squares of sheets treated alike.

APPENDIX A (Continued)

TABLE 2. COMPILATION OF DATA FROM MEASUREMENTS MADE AT THE FIFTH INTERVAL

State	Cottons	Y Values Assigned	Thread Count (Yarns per inch) Warp	Thread Count (Yarns per inch) Filling	Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent) Warp	Dimensional Change (Per Cent) Filling	Tearing Strength 100 G/CM Warp	Tearing Strength 100 G/CM Filling	Breaking Strength (Pounds) Warp	Breaking Strength (Pounds) Filling	Elongation (Per Cent) Warp	Elongation (Per Cent) Filling
Alabama	1	25	449.00	419.00	29.00	+0.60	+1.7	92.17	78.68	347.80	400.80	84.70	95.50
	2	26	446.00	425.00	29.06	-1.8	+3.0	89.33	79.08	335.90	413.90	91.70	102.90
	3	27	444.00	426.00	29.05	-0.3	-0.4	91.29	75.36	321.40	396.00	109.70	115.70
	4	28	451.00	414.00	29.32	-1.6	+5.2	82.25	71.10	319.00	378.50	93.30	103.20
	Total	29	1790.00	1684.00	116.43	-3.10	+9.5	355.04	304.22	1324.10	1589.20	379.40	417.30
	S.T.A.	30	15.0004	21.6665	0.0529	11.1483	17.0550	26.6672	8.3749	240.0093	144.9956	8.7799	10.8316
Missouri	1	31	443.00	426.00	29.80	-7.5	+2.9	91.72	79.01	315.00	396.00	99.90	104.30
	2	32	451.00	439.00	30.08	-6.1	+3.7	81.41	76.64	329.30	406.40	100.70	109.00
	3	33	439.00	432.00	29.64	+0.2	+1.1	81.57	69.11	303.70	368.90	114.00	117.30
	4	34	443.00	428.00	29.95	-5.3	+2.3	80.22	68.51	322.40	363.70	107.80	115.20
	Total	35	1776.00	1725.00	119.47	-18.7	+10.0	334.92	293.27	1270.40	1535.00	422.40	445.80
	S.T.A.	36	25.3333	34.1665	0.0423	13.5050	1.8133	7.4878	4.7302	107.2697	236.8887	3.7566	7.5366
North Carolina	1	37	444.00	422.00	29.45	-9.8	+9.7	81.13	73.90	309.90	384.10	95.90	97.50
	2	38	444.00	436.00	29.07	-9.6	+13.7	79.20	74.08	297.90	386.70	99.50	95.20
	3	39	442.00	433.00	29.15	-10.2	+4.6	71.54	63.59	302.10	369.10	110.60	110.20
	4	40	441.00	429.00	29.16	-10.4	+13.3	74.14	64.40	294.80	366.00	104.90	106.70
	Total	41	1771.00	1720.00	116.83	-40.0	+41.3	306.01	275.97	1204.70	1505.90	410.90	409.60
	S.T.A.	42	20.8332	28.9998	0.0297	6.3867	7.2383	22.9307	10.1679	113.1783	115.6309	5.7583	6.1099
Oklahoma	1	43	462.00	423.00	30.22	-4.3	+2.2	98.06	84.61	312.60	365.40	83.40	97.40
	2	44	460.00	427.00	30.03	-3.2	+2.5	93.82	80.10	313.40	336.50	88.60	95.30
	3	45	462.00	428.00	30.26	-3.1	+2.1	85.43	72.51	313.70	325.90	95.60	105.60
	4	46	461.00	424.00	30.81	-5.4	+1.3	83.89	72.49	308.60	368.70	96.00	107.20
	Total	47	1845.00	1702.00	121.32	-16.0	+8.1	361.20	309.71	1248.30	1396.50	363.60	405.50
	S.T.A.	48	8.1667	19.0000	0.0492	5.8900	2.4050	7.7740	9.7455	209.6747	334.9309	8.2066	16.4549

APPENDIX A (Continued)

TABLE 3. COMPILATION OF DATA FROM MEASUREMENTS MADE AT THE FIFTEENTH INTERVAL

State	Cottons	Y Values Assigned	Thread Count (Yarns per inch) Warp	Thread Count (Yarns per inch) Filling	Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent) Warp	Dimensional Change (Per Cent) Filling	Tearing Strength 100 G/CM Warp	Tearing Strength 100 G/CM Filling	Breaking Strength (Pounds) Warp	Breaking Strength (Pounds) Filling	Elongation (Per Cent) Warp	Elongation (Per Cent) Filling
Alabama	1	49	458.00	427.00	29.53	-5.1	-1.3	77.36	70.92	319.50	383.90	93.20	103.70
	2	50	457.00	431.00	28.81	-4.1	0.0	77.22	66.77	312.50	372.30	93.30	104.70
	3	51	453.00	434.00	29.38	-6.1	-7.2	74.88	63.16	313.20	357.80	105.30	115.66
	4	52	456.00	434.00	29.46	-7.9	-2.0	73.25	63.43	309.40	367.50	101.70	114.70
	Total	53	1824.00	1726.00	117.18	-23.2	-10.5	302.71	264.28	1254.60	1481.50	393.50	438.70
	S.T.A.	54	21.6670	26.3330	0.1267	10.1600	9.2217	7.5390	8.4403	65.9761	180.8521	6.7983	3.9250
Missouri	1	55	444.00	419.00	29.60	-7.6	+7.8	73.41	67.50	290.10	353.20	92.40	95.10
	2	56	446.00	429.00	29.62	-7.2	+9.0	69.04	64.22	290.80	361.60	96.30	95.00
	3	57	443.00	426.00	29.28	-4.7	+7.1	69.01	60.27	272.60	342.30	106.20	106.90
	4	58	443.00	424.00	29.79	-4.0	+8.5	68.16	59.84	285.40	345.20	101.80	103.40
	Total	59	1776.00	1698.00	118.29	-23.5	+32.4	279.62	251.83	1138.90	1402.30	396.70	400.40
	S.T.A.	60	9.0000	25.6665	0.0544	15.0950	4.9367	1.9099	1.5544	81.0145	92.3950	4.3682	5.5900
North Carolina	1	61	450.00	429.00	29.13	-10.5	+4.6	71.08	61.73	261.70	313.70	85.60	88.30
	2	62	452.00	433.00	28.93	-11.2	+1.0	66.64	59.87	260.20	309.10	84.50	92.40
	3	63	449.00	437.00	28.67	-12.7	+1.4	62.37	52.69	251.50	290.40	95.80	101.30
	4	64	456.00	427.00	28.91	-8.3	+3.6	62.91	53.90	253.50	297.80	93.60	101.40
	Total	65	1807.00	1726.00	115.64	-42.7	+10.6	263.00	228.19	1026.90	1211.00	359.50	383.40
	S.T.A.	66	20.1670	21.9998	0.0340	5.5650	8.1600	2.4316	4.2596	47.1049	143.0493	5.5950	10.9566
Oklahoma	1	67	456.00	427.00	29.99	-12.4	+5.6	76.99	65.56	283.50	315.90	120.70	126.80
	2	68	457.00	435.00	30.11	-10.0	+4.1	72.60	62.92	288.10	343.70	96.20	105.00
	3	69	457.00	433.00	30.20	-11.4	+3.7	68.86	58.60	271.70	320.30	107.70	113.70
	4	70	459.00	428.00	30.47	-10.8	+1.9	69.50	60.49	277.10	321.10	104.60	113.70
	Total	71	1829.00	1723.00	120.77	-44.6	+15.3	287.95	247.57	1120.40	1301.00	429.20	459.20
	S.T.A.	72	3.1667	16.4998	0.0996	6.5467	3.9783	10.3342	8.5891	107.5997	202.3801	17.5099	15.1633

APPENDIX B

MEAN RESULTS OF PHYSICAL MEASUREMENTS APPLIED TO FOUR TYPES OF COTTON SHEETING USED IN FOUR STATES

TABLE 1. MEANS OF MEASUREMENTS OF SIX IDENTICAL SHEETS WITHIN EACH COTTON TYPE

ZERO INTERVAL

State	Cottons	Thread Count (Yarns per inch) Warp	Thread Count (Yarns per inch) Filling	Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent) Warp	Dimensional Change (Per Cent) Filling	Tearing Strength 100 G/CM Warp	Tearing Strength 100 G/CM Filling	Breaking Strength (Pounds) Warp	Breaking Strength (Pounds) Filling	Elongation (Per Cent) Warp	Elongation (Per Cent) Filling
Alabama	1	75.7	70.0	4.86			12.18	11.42	62.8	77.0	17.4	19.8
	2	75.7	70.7	4.78			12.01	11.20	61.0	69.8	17.9	19.1
	3	76.0	70.8	4.85			11.34	10.35	59.7	70.8	20.0	23.3
	4	76.5	70.2	4.84	No		10.82	10.10	57.8	67.9	19.5	21.2
Missouri	1	75.2	70.2	4.96	measurements		12.94	12.12	58.3	71.8	15.5	17.8
	2	75.3	70.8	4.94			12.47	11.74	60.0	67.9	15.4	18.0
	3	74.8	70.8	4.91	made		10.74	9.68	56.6	64.2	17.8	20.0
	4	76.0	70.7	5.04			10.36	9.76	59.4	66.9	17.6	20.0
					at this							
North Carolina	1	75.8	70.2	4.89			12.64	11.52	59.4	65.8	14.8	17.8
	2	75.7	71.0	4.85	interval		14.48	12.82	55.0	65.1	15.0	17.8
	3	75.2	70.7	4.84			9.68	8.67	57.6	64.8	17.5	20.2
	4	75.8	70.0	4.91			11.94	10.47	56.4	61.6	16.5	19.9
Oklahoma	1	76.3	69.3	5.04			11.88	11.22	59.8	72.2	15.7	19.2
	2	76.3	70.8	5.00			11.50	10.85	58.9	68.0	14.7	18.6
	3	77.0	70.5	5.00			11.26	10.23	57.6	67.3	17.1	21.8
	4	76.8	69.5	5.03			11.96	10.67	57.1	65.2	16.8	20.7

TABLE 2. MEANS OF MEASUREMENTS OF SIX IDENTICAL SHEETS WITHIN EACH COTTON TYPE

APPENDIX B (Continued)

FIFTH INTERVAL

State	Cottons	Thread Count (Yarns per inch) Warp	Thread Count (Yarns per inch) Filling	Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent) Warp	Dimensional Change (Per Cent) Filling	Tearing Strength 100 G/CM Warp	Tearing Strength 100 G/CM Filling	Breaking Strength (Pounds) Warp	Breaking Strength (Pounds) Filling	Elongation (Per Cent) Warp	Elongation (Per Cent) Filling
Alabama	1	74.8	69.8	4.83	+0.1	+0.3	15.36	13.11	58.0	66.8	14.1	15.9
	2	74.3	70.8	4.84	-0.3	+0.5	14.89	13.18	56.0	69.0	15.3	17.2
	3	74.0	71.0	4.84	0.0	0.0	15.22	12.56	53.6	66.0	18.3	19.3
	4	75.2	69.0	4.89	-0.3	+0.9	13.71	11.85	53.2	63.1	15.6	17.2
Missouri	1	73.8	71.0	4.97	-1.2	+0.5	15.29	13.17	52.5	66.0	16.6	17.4
	2	75.2	73.2	5.01	-1.0	+0.6	13.57	12.77	54.9	67.7	16.8	18.2
	3	73.2	72.0	4.94	0.0	+0.2	13.60	11.52	50.6	61.5	19.0	19.6
	4	73.8	71.3	4.99	-0.9	+0.4	13.37	11.42	53.7	60.6	18.0	19.2
North Carolina	1	74.0	70.3	4.91	-1.6	+1.6	13.52	12.32	51.6	64.0	16.0	16.2
	2	74.0	72.7	4.84	-1.6	+2.3	13.20	12.35	49.6	64.5	16.6	15.9
	3	73.7	72.7	4.86	-1.7	+0.8	11.92	10.60	50.3	61.5	18.4	18.4
	4	73.5	71.7	4.86	-1.7	+2.2	12.36	10.73	49.1	61.0	17.5	17.8
Oklahoma	1	77.0	70.5	5.04	-0.7	+0.4	16.34	14.10	52.1	60.9	13.9	16.2
	2	76.7	71.2	5.00	-0.5	+0.4	15.64	13.35	52.2	56.1	14.8	15.9
	3	77.0	71.3	5.04	-0.5	+0.4	14.24	12.09	52.3	54.3	15.9	17.6
	4	76.8	70.7	5.13	-0.9	+0.2	13.98	12.08	51.4	61.4	16.0	17.9

APPENDIX B (Continued)

TABLE 3. MEANS OF MEASUREMENTS OF SIX IDENTICAL SHEETS WITHIN EACH COTTON TYPE

FIFTEENTH INTERVAL

State	Cottons	Thread Count (Yarns per inch)		Fabric Weight (Oz.sq.yd)	Dimensional Change (Per Cent)		Tearing Strength 100 G/CM		Breaking Strength (Pounds)		Elongation (Per Cent)	
		Warp	Filling		Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
Alabama	1	76.3	71.2	4.92	-0.8	-0.2	12.89	11.82	53.3	64.0	15.5	17.3
	2	76.2	71.8	4.80	-0.7	0.0	12.87	11.13	52.1	62.0	15.6	17.4
	3	75.5	72.3	4.90	-1.0	-1.2	12.48	10.53	52.2	59.6	17.6	19.3
	4	76.0	72.3	4.91	-1.3	-0.3	12.21	10.57	51.6	61.3	17.0	19.1
Missouri	1	74.0	69.8	4.93	-1.3	+1.3	12.24	11.25	48.4	58.9	15.4	15.9
	2	74.3	71.5	4.94	-1.2	+1.5	11.51	10.70	48.5	60.3	16.1	15.8
	3	73.8	71.0	4.88	-0.8	+1.2	11.50	10.04	45.4	57.0	17.7	17.8
	4	73.8	70.7	4.96	-0.6	+1.4	11.36	9.97	47.6	57.5	17.0	17.2
North Carolina	1	75.0	71.5	4.86	-1.8	+0.8	11.85	10.29	43.6	52.3	14.3	14.7
	2	75.3	72.2	4.82	-1.9	+0.2	11.11	9.98	43.4	51.5	14.1	15.4
	3	74.8	72.8	4.78	-2.1	+0.2	10.40	8.78	41.9	48.4	16.0	16.9
	4	76.0	71.1	4.82	-1.4	+0.6	10.49	8.98	42.2	49.6	15.6	16.9
Oklahoma	1	76.0	71.2	5.00	-2.1	+0.9	12.83	10.93	47.2	52.6	20.1	21.1
	2	76.2	72.5	5.01	-1.7	+0.7	12.10	10.47	48.0	57.3	16.0	17.5
	3	76.2	72.2	5.03	-1.9	+0.6	11.47	9.77	45.3	53.4	18.0	19.0
	4	76.5	71.3	5.08	-1.8	+0.3	11.58	10.08	46.2	53.5	17.4	19.0

APPENDIX C

ANALYSIS OF VARIANCE TABLES FOR PHYSICAL MEASUREMENTS--ZERO-FIVE INTERVALS

TABLE 1. ANALYSIS OF VARIANCE OF WARP THREAD COUNT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	5.1718	1.7240	1.08
Low vs. high	1	0.0312	0.0312	0.02
Between lows	1	0.0938	0.0938	0.06
Between highs	1	5.0468	5.0468	3.17
Washing Intervals	1	55.2500	55.2500	5.55
Locations	3	136.5468	45.5156	77.60
C x W	3	4.6406	1.5468	2.64
C x L	9	14.3125	1.5902	2.71
W x L	3	29.8594	9.9531	16.97
C x W x L	9	6.0000	0.6666	1.14
Sheets treated alike	160	93.8356	0.5864	
Total	191			

APPENDIX C (continued)

TABLE 2. ANALYSIS OF VARIANCE OF FILLING THREAD COUNT

Source	Degrees of Freedom	Sum of Squares	Mean Square	*F* Values
Cottons	3	52.1250	17.3750	20.74
Low vs. high	1	0.0196	0.0196	0.03
Between lows	1	36.2617	36.2617	43.30
Between highs	1	15.8437	15.8437	18.92
Washing Intervals	1	28.5156	28.5156	4.83
Locations	3	30.2031	10.0677	12.02
C x W	3	3.2734	1.0911	1.30
C x L	9	4.9218	0.5469	0.65
W x L	3	17.6953	5.8984	7.04
C x W x L	9	11.1796	1.2422	1.48
Sheets treated alike	160	133.9986	0.8374	
Total	191			

APPENDIX C (continued)

TABLE 3. ANALYSIS OF VARIANCE OF FABRIC WEIGHT

Source	Degrees of Freedom	Sum of Squares	Mean Square	$\underline{F}$ Values
Cottons	3	0.0852	0.0286	5.84
Low vs. high	1	0.0082	0.0082	1.80
Between lows	1	0.0160	0.0160	3.28
Between highs	1	0.0610	0.0610	12.44
Washing Intervals	1	0.0139	0.0139	5.88
Locations	3	1.1594	0.3864	168.28
C x W	3	0.0066	0.0022	0.94
C x L	9	0.0449	0.0049	2.10
W x L	3	0.0110	0.0036	1.54
C x W x L	9	0.0676	0.0075	3.17
Sheets treated alike	160	0.3787	0.0024	
Total	191			

APPENDIX C (continued)

TABLE 4. ANALYSIS OF VARIANCE OF WARP DIMENSIONAL CHANGE

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	1.0652	0.3551	1.54
Low vs. high	1	0.1633	0.1633	0.70
Between lows	1	0.0010	0.0010	0.00
Between highs	1	0.9009	0.9009	3.90
Washing Intervals	1	31.5252	31.5252	6.46
Locations	3	14.6268	4.8756	21.12
C x W	3	1.0652	0.3551	1.54
C x L	9	2.4277	0.2697	1.16
W x L	3	14.6268	4.8756	21.12
C x W x L	9	2.4277	0.2697	1.16
Sheets treated alike	160	36.9300	0.2308	
Total	191			

APPENDIX C (continued)

TABLE 5. ANALYSIS OF VARIANCE OF FILLING DIMENSIONAL CHANGE

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	3.1880	1.0626	5.96
Low vs. high	1	0.5105	0.5105	2.86
Between lows	1	0.4266	0.4266	2.39
Between highs	1	2.2509	2.2509	12.63
Washing Intervals	1	24.7250	24.7250	4.60
Locations	3	16.1405	5.3801	30.19
C x W	3	3.1880	1.0626	5.96
C x L	9	3.0054	0.3339	1.87
W x L	3	16.1406	5.3801	30.19
C x W x L	9	3.0054	0.3339	1.87
Sheets treated alike	160	28.5116	0.1782	
Total	191			

APPENDIX C (continued)

TABLE 6. ANALYSIS OF VARIANCE OF WARP TEARING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	88.1460	29.3820	6.84
Low vs. high	1	85.9208	85.9208	20.01
Between lows	1	2.1304	2.1304	0.50
Between highs	1	0.0948	0.0948	0.02
Washing Intervals	1	270.7968	270.7968	13.48
Locations	3	22.8161	7.6053	12.04
C x W	3	12.3061	4.1020	1.38
C x L	9	38.6384	4.2932	6.80
W x L	3	60.2302	20.0767	31.79
C x W x L	9	26.7160	2.9684	4.70
Sheets treated alike	160	101.0443	0.6315	
Total	191			

APPENDIX C (continued)

TABLE 7. ANALYSIS OF VARIANCE OF FILLING TEARING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	114.0449	38.0150	14.96
Low vs. high	1	113.2366	113.2366	44.56
Between lows	1	0.1890	0.1890	0.07
Between highs	1	0.6193	0.6193	0.24
Washing Intervals	1	112.5314	112.5314	20.20
Locations	3	11.2490	3.7496	9.96
C x W	3	3.8005	1.2668	1.02
C x L	9	22.8664	2.5407	6.74
W x L	3	16.7065	5.5688	14.78
C x W x L	9	11.2238	1.2471	3.31
Sheets treated alike	160	60.2598	0.3766	
Total	191			

APPENDIX C (continued)

TABLE 8. ANALYSIS OF VARIANCE OF WARP BREAKING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	*F* Values
Cottons	3	139.3672	46.4557	1.92
Low vs. high	1	122.1016	122.1016	5.06
Between lows	1	17.2539	17.2539	0.72
Between highs	1	0.0127	0.0127	0.00
Washing Intervals	1	1729.6797	1729.6797	250.84
Locations	3	412.4453	137.4818	19.93
C x W	3	6.5546	2.1848	0.32
C x L	9	217.0781	24.1198	3.50
W x L	3	21.7500	7.2500	1.05
C x W x L	9	19.6640	2.1848	0.32
Sheets treated alike	160	1103.2972	6.8956	
Total	191			

APPENDIX C (continued)

TABLE 9. ANALYSIS OF VARIANCE OF FILLING BREAKING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	659.6328	219.8776	8.43
Low vs. high	1	554.8828	554.8828	21.27
Between lows	1	102.0859	102.0859	3.91
Between highs	1	2.6641	2.6641	0.10
Washing Intervals	1	1252.5469	1252.5469	8.20
Locations	3	967.5703	322.5234	36.82
C x W	3	119.1016	39.7005	1.34
C x L	9	234.7109	26.0790	2.98
W x L	3	458.3672	152.7890	17.44
C x W x L	9	266.1094	29.5677	3.38
Sheets treated alike	160	1401.6612	8.7604	
Total	191			

APPENDIX C (continued)

TABLE 10. ANALYSIS OF VARIANCE OF WARP FABRIC ELONGATION

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	200.6186	66.8728	52.26
Low vs. high	1	181.3520	181.3520	141.74
Between lows	1	1.9268	1.9268	1.50
Between highs	1	17.3398	17.3398	13.55
Washing Intervals	1	7.8418	7.8418	0.18
Locations	3	80.9731	26.9910	56.44
C x W	3	7.0449	2.3483	2.28
C x L	9	11.5142	1.2794	2.67
W x L	3	133.1514	44.3838	92.82
C x W x L	9	9.2578	1.0286	2.15
Sheets treated alike	160	76.5061	0.4782	
Total	191			

APPENDIX C (continued)

TABLE 11. ANALYSIS OF VARIANCE OF FILLING FABRIC ELONGATION

Source	Degrees of Freedom	Sum of Squares	Mean Square	*F* Values
Cottons	3	219.1572	75.0524	36.42
Low vs. high	1	204.3935	204.3935	101.91
Between lows	1	0.0372	0.0372	0.02
Between highs	1	14.7265	14.7265	7.34
Washing Intervals	1	236.5176	236.5176	9.82
Locations	3	31.3955	10.4652	15.55
C x W	3	6.8388	2.2796	3.38
C x L	9	18.0508	2.0056	2.98
W x L	3	72.2119	24.0706	35.77
C x W x L	9	8.2539	0.9171	1.36
Sheets treated alike	160	107.6679	0.6729	
Total	191			

APPENDIX D

ANALYSIS OF VARIANCE TABLES FOR PHYSICAL MEASUREMENTS--

ZERO-FIVE-FIFTEEN INTERVALS

TABLE 1. ANALYSIS OF VARIANCE OF WARP THREAD COUNT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	9.0000	3.0000	4.87
Low vs. high	1	1.0000	1.0000	1.62
Between lows	1	0.3403	0.3403	0.52
Between highs	1	8.0270	8.0270	13.03
Washing Intervals	2	55.3125	27.6562	2.98
Locations	3	182.4375	60.8125	98.72
C x W	6	4.3500	0.7250	1.18
C x L	9	10.5200	1.1680	1.90
W x L	6	55.5468	9.2578	15.02
C x W x L	18	15.1700	0.8420	1.36
Sheets treated alike	240	147.8363	0.6160	
Total	287			

APPENDIX D (continued)

TABLE 3. ANALYSIS OF VARIANCE OF FABRIC WEIGHT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	0.1249	0.0416	4.12
Low vs. high	1	0.0106	0.0106	1.05
Between lows	1	0.0283	0.0283	2.80
Between highs	1	0.0860	0.0860	8.51
Washing Intervals	2	0.0266	0.0133	0.84
Locations	3	1.6586	0.5528	193.36
C x W	6	0.0073	0.0012	0.42
C x L	9	0.0918	0.0101	3.53
W x L	6	0.0948	0.0158	5.46
C x W x L	18	0.0964	0.0054	1.85
Sheets treated alike	240	0.6934	0.0028	
Total	287			

APPENDIX D (continued)

TABLE 4. ANALYSIS OF VARIANCE OF WARP DIMENSIONAL CHANGE

Source	Degrees of Freedom	Sum of Squares	Mean Square	$\underline{F}$ Values
Cottons	3	0.4940	0.1646	0.53
Low vs. high	1	0.2112	0.2112	0.68
Between lows	1	0.0803	0.0803	0.26
Between highs	1	0.2025	0.2025	0.65
Washing Intervals	2	94.3308	47.1654	12.90
Locations	3	24.5746	8.1915	26.46
C x W	6	2.2038	0.3673	1.18
C x L	9	4.8679	0.5408	1.74
W x L	6	21.9266	3.6544	11.80
C x W x L	18	4.5242	0.2513	0.81
Sheets treated alike	240	74.2967	0.3096	
Total	287			

APPENDIX D (continued)

TABLE 5. ANALYSIS OF VARIANCE OF FILLING DIMENSIONAL CHANGE

Source	Degrees of Freedom	Sum of Squares	Mean Square	*F* Values
Cottons	3	5.3206	1.7735	4.02
Low vs. high	1	1.9503	1.9503	4.42
Between lows	1	0.1003	0.1003	0.23
Between highs	1	3.2700	3.2700	7.40
Washing Intervals	2	25.9627	12.9814	1.60
Locations	3	22.7112	7.5704	33.15
C x W	6	4.2009	0.7002	1.83
C x L	9	3.9742	0.4416	1.93
W x L	6	48.5386	8.0898	35.42
C x W x L	18	6.8854	0.3825	1.68
Sheets treated alike	240	54.8083	0.2284	
Total	287			

APPENDIX D (continued)

TABLE 6. ANALYSIS OF VARIANCE OF WARP TEARING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	98.5332	32.8444	9.91
Low vs. high	1	93.2070	93.2070	28.12
Between lows	1	5.3055	5.3055	1.60
Between highs	1	0.0207	0.0207	0.01
Washing Intervals	2	354.6420	177.3210	15.60
Locations	3	49.1782	16.3927	31.92
C x W	6	18.7148	3.1191	1.46
C x L	9	29.8242	3.3138	6.45
W x L	6	68.2012	11.3668	22.13
C x W x L	18	38.5136	2.1396	4.16
Sheets treated alike	240	123.2590	0.5136	
Total	287			

APPENDIX D (continued)

TABLE 7. ANALYSIS OF VARIANCE OF FILLING TEARING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	$\underline{F}$ Values
Cottons	3	134.0440	44.6813	21.23
Low vs. high	1	131.4370	131.4370	62.46
Between lows	1	1.8200	1.8200	0.86
Between highs	1	0.7870	0.7870	0.37
Washing Intervals	2	208.9067	104.4534	23.81
Locations	3	29.6489	9.8830	28.54
C x W	6	10.0654	1.6776	1.84
C x L	9	18.9409	2.1045	6.08
W x L	6	26.3198	4.3866	12.66
C x W x L	18	16.3398	0.9078	2.62
Sheets treated alike	240	83.1032	0.3462	
Total	287			

APPENDIX D (continued)

TABLE 8. ANALYSIS OF VARIANCE OF WARP BREAKING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	191.0078	63.6692	3.27
Low vs. high	1	176.0156	176.0156	9.04
Between lows	1	13.3798	13.3798	0.69
Between highs	1	1.6124	1.6124	0.08
Washing Intervals	2	6117.1953	3058.5977	71.78
Locations	3	1270.9453	423.6484	72.36
C x W	6	14.7266	2.4544	0.42
C x L	9	175.2500	19.4722	3.33
W x L	6	255.6640	42.6106	7.28
C x W x L	18	84.4766	4.6931	0.80
Sheets treated alike	240	1404.9924	5.8541	
Total	287			

APPENDIX D (continued)

TABLE 9. ANALYSIS OF VARIANCE OF FILLING BREAKING STRENGTH

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Values
Cottons	3	707.8281	235.9427	28.03
Low vs. high	1	664.3125	664.3125	78.92
Between lows	1	43.3359	43.3359	5.15
Between highs	1	0.1797	0.1797	0.02
Washing Intervals	2	6581.5625	3290.7812	23.97
Locations	3	2341.7500	780.5833	92.73
C x W	6	216.5781	36.0963	1.42
C x L	9	126.9531	14.1059	1.68
W x L	6	825.5625	137.2604	16.30
C x W x L	18	459.1250	25.5069	3.03
Sheets treated alike	240	2020.3377	8.4181	
Total	287			

APPENDIX D (continued)

TABLE 10. ANALYSIS OF VARIANCE OF WARP FABRIC ELONGATION

Source	Degrees of Freedom	Sum of Squares	Mean Square	$\underline{F}$ Values
Cottons	3	222.6074	74.2025	18.13
Low vs. high	1	201.8379	201.8379	49.31
Between lows	1	0.4443	0.4443	0.11
Between highs	1	20.3252	20.3252	4.96
Washing Intervals	2	9.8018	4.9008	0.11
Locations	3	45.2598	15.0865	32.68
C x W	6	29.4004	4.9001	2.00
C x L	9	36.8418	4.0935	8.86
W x L	6	270.3115	45.0519	97.60
C x W x L	18	44.3057	2.4614	5.33
Sheets treated alike	240	110.7775	0.4616	
Total	287			

APPENDIX D (continued)

TABLE 11. ANALYSIS OF VARIANCE OF FILLING FABRIC ELONGATION

Source	Degrees of Freedom	Sum of Squares	Mean Square	*F* Values
Cottons	3	244.5029	81.5010	18.89
Low vs. high	1	230.7705	230.7705	53.49
Between lows	1	1.5405	1.5405	0.36
Between highs	1	12.1919	12.1919	2.83
Washing Intervals	2	310.2646	155.1323	6.16
Locations	3	102.9228	34.3076	57.46
C x W	6	24.8838	4.1472	1.69
C x L	9	38.8271	4.3141	7.22
W x L	6	151.0742	25.1790	42.17
C x W x L	18	44.2217	2.4568	4.11
Sheets treated alike	240	143.3028	0.5971	
Total	287			